



Australian Government
Geoscience Australia

AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 2012





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Department of Resources, Energy and Tourism

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Geoscience Australia

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ISSN 1327-1466

GeoCat No. 79672

Amended 13 June 2014. Minor corrections made.

Bibliographic reference: Geoscience Australia 2013. Australia's Identified Mineral Resources 2012. Geoscience Australia, Canberra.

Front cover:

Dragline moving overburden at the Ensham coal mine, 35 km east-northeast of Emerald in the Bowen Basin, Queensland.

Design and layout:

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Executive Summary

Australia's Identified Mineral Resources is an annual national assessment that takes a long-term view of mineral resources likely to be available for mining. The highest category in the national inventory is Economic Demonstrated Resources (EDR) which, in essence, combines the Joint Ore Reserve Committee (JORC) Code categories of Ore Reserves and most of the Measured and Indicated Resources. JORC Code Ore Reserves of commodities are included for comparison, which provides a short to medium-term view of mineral stocks. The assessment also includes evaluations of long-term trends in mineral resources, world rankings, summaries of significant exploration results and brief reviews of mining industry developments.

Australia's EDR for the following 20 mineral commodities increased during 2011 - antimony, black coal, brown coal, cobalt, copper, gold, iron ore, lead, lithium, manganese, niobium, phosphate rock, platinum group elements, rare earth oxides, rutile, silver, tantalum, uranium, zinc and zircon. However, during the same period there was a decrease in the EDR for five commodities: diamonds, ilmenite, molybdenum, tin and vanadium. EDR for bauxite, chromium, fluorine, magnesite, nickel, shale oil, thorium and tungsten remained at levels similar to those reported in 2010.

Australia's EDR of gold, iron ore, lead, rutile, zircon, nickel, uranium and zinc are the world's largest, while antimony, bauxite, black coal, recoverable brown coal, cobalt, copper, diamond, ilmenite, lithium, manganese, niobium, silver, tantalum, tungsten and vanadium all rank in the top six worldwide.

Australia's EDR of **bauxite** were estimated to be some 5665 million tonnes (Mt) in 2011 (unchanged from 2010), ranking second in the world behind the Republic of Guinea and ahead of Brazil, Vietnam, Jamaica and India. Australia was the world's leading producer of bauxite and alumina in 2011 and the fifth largest aluminium producer. Australia's aluminium industry continues to be a highly integrated sector of mining, refining, smelting and semi-fabrication and is of major economic importance nationally and globally. Australia's aluminium industry is underpinned by vast resources of bauxite at Cape York in Queensland (Qld), at Gove in the Northern Territory (NT) and in the Darling Range southeast of Perth in Western Australia (WA). Rio Tinto received State approval for its South of Embley project in Qld, which will extend the Weipa operations by up to 40 years.

In 2011, the estimate of Australia's recoverable **black coal** EDR was revised upwards from the 2010 total by 17% to 57 538 Mt. The resource constitutes 6% of the world's recoverable black coal EDR. Globally, Australia is ranked fifth behind the United States, the Russian Federation, China and India in terms of recoverable economic coal resources. Most of these resources are located in Qld (61%) and New South Wales (NSW; 36%). The Bowen Basin in Qld and the Sydney Basin in NSW dominate black coal production in Australia and contain 65% of the nation's recoverable black coal EDR. Significant black coal resources are also found in the Surat, Clarence-Moreton and Galilee Basins (Qld) and in the Gunnedah Basin (NSW). At 2011 rates of production, Australia's black coal EDR will support 125 years of production.

Between 2010 and 2011, the estimate of Australia's recoverable **brown coal** EDR (44 219 Mt) remained unchanged. Approximately 19% of the world's recoverable brown coal resources are located in Australia and the nation is ranked second behind the United States in terms of recoverable brown coal EDR. All of Australia's recoverable brown coal EDR is located in Victoria (Vic) with approximately 93% in the Latrobe Valley. During 2011, brown coal production in Australia was estimated at 66.7 Mt. Brown coal mined in Australia is used almost exclusively for domestic electricity generation and at current rates of extraction the resource base will support 663 years of production.

Australia's EDR of **copper** rose by one million tonnes in 2011 to 86.7 Mt, an increase of 1%. Australia has the third largest economic resources of copper at 13% after Chile and Peru. South Australia (SA) has 67% of the national total, mainly in the Olympic Dam deposit, followed by Qld with 13% and NSW with 12% of EDR. In 2011, mine production of copper rose by 10% and exports totalled \$8.6 billion, up 14%. Spending on exploration rose by 51% with expenditure in SA and Qld accounting for 33% each of all copper exploration expenditure. New copper mines approaching first production in 2011 were Cadia East (NSW), DeGrussa (WA) and underground at Prominent Hill (SA). Studies into a major expansion for Northparkes (NSW) were commenced and the major expansion for Olympic Dam (SA) was delayed to investigate a less capital-intensive design. Copper mines recommencing production in 2011 included Lady Annie (Qld), Mount Gordon (Qld), Osborne (Qld), Kanmantoo (SA) and Mineral Hill (NSW).

Diamond production continued at the Argyle and Ellendale mines in WA throughout 2011, with a total of 7.6 million carats (Mc) produced. Australia's EDR of diamonds decreased by 7% in 2011 to 272.5 Mc. The Argyle diamond mine continues to dominate production and hosts most of Australia's EDR of diamonds.

Australia's EDR of **gold** in 2011 was 9153 tonnes, an increase of 9% over 2010. Australia had the world's largest resources of gold by country with 17% of the estimated total, while South Africa with 6000 tonnes and Russia with 5000 tonnes had the second and third largest shares, respectively. EDR rose in all States and the NT and WA continued to dominate the national resource inventory with 4058 tonnes or 44% of the total. South Australia with 2731 tonnes and NSW with 1645 tonnes contributed the next highest tonnages of metal in resources. Gold production for the year fell minimally by 2 tonnes to 258 tonnes while export of refined gold also fell from 330 to 308 tonnes. Gold prices rose during the year from at about US\$1400/oz to US\$1600/oz and coincided with increased exploration expenditure on the commodity of \$85 million, bringing the annual total to \$709 million for 2011.

Because of major changes in Australia's **iron ore** mining industry and the development of large magnetite deposits in Australia, Geoscience Australia has estimated national resources of iron in two categories:

- Iron ore (tonnes)
- Contained iron (Fe) (tonnes).

EDR of iron ore increased by 9% to 37 762 Mt during 2011 with the EDR of contained Fe estimated to be 18 152 Mt. Western Australia has the largest share of these resources with 94% of Australia's EDR, the majority of which is in the Pilbara region. Australia has the world's largest EDR with 22% of the world iron ore. This is followed by Brazil with 17% of the world EDR. Western Australia produced 474 Mt, or 97% of Australia's total production of iron ore in 2011. Iron ore exploration expenditure in Australia for 2011 totalled \$905.3 million, a 64% increase on the \$553.1 million spent in 2010. Exploration on iron ore for 2011 also accounted for 25% of Australia's total mineral exploration expenditure.

Australia's EDR of **lithium** increased by 208% to 1006 kilotonnes (kt) in 2011, ranking it third largest globally, with 7.7% of the world's economic resources. All of Australia's EDR of lithium occur within hard rock pegmatite deposits in WA. The bulk of the increase in Australia's EDR of lithium reflects a large addition to resources at the Greenbushes spodumene deposit, the world's largest and highest grade spodumene deposit.

Australia's EDR of **magnesite** totalled 330 Mt representing about 4% of the world's economic resources of magnesite. South Australia has the largest share of these resources with 71% followed by Qld with 19%. The Kunwarara deposit in Qld is the world's largest known resource of ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

Australia's EDR of **manganese ore** increased by 7% to 197 Mt in 2011, ranking Australia's resources as the world's fifth largest. The bulk of the EDR occur in the NT and WA. Australia's mine production of manganese ore reached record levels of 7 Mt in 2011, and is ranked second behind China.

The regions containing the major proportion of Australia's **mineral sands** resources (ilmenite, rutile and zircon) are the Perth Basin north of Perth in WA, the Murray Basin (NSW, Vic, and SA) and the newly emerging heavy mineral sands regions in the Eucla Basin (WA and SA). In 2011, EDR decreased by 5.3% to 188.9 Mt for ilmenite, increased by 18.3% to 46.6 Mt for zircon and increased by 15.7% to 27.2 Mt for rutile. Australia's rutile and zircon resources are ranked number one in the world, while ilmenite resources are the second largest worldwide behind China.

Australia's EDR of **molybdenum** decreased by just under 50% to 167 kt in 2011, ranking it eighth globally with 1.7% of the world's economic resources. The decrease in Australia's EDR largely reflected the current uneconomic status of Australia's largest molybdenum deposit at Spinifex Ridge in WA.

Australia's EDR of **nickel**, which at 26.8% is the world's largest, decreased by 13.8% from 24.0 Mt in 2010 to 20.7 Mt in 2011. Western Australia remains the largest holder of nickel resources with 90.7% of total Australian EDR made up of both sulphide and lateritic deposits. Nickel production resumed in 2011 at the Ravensthorpe lateritic nickel mine and at the Maggie Hays sulphide deposit.

Australia's EDR of **niobium** increased by 53% to 205 kt in 2011, ranking Australia the second largest in the world behind Brazil. The bulk of the EDR are associated with the Toongi deposit, 20 kilometres south of Dubbo in NSW.

Changes in the **phosphate** mining industry have resulted in Geoscience Australia estimating national resources of phosphate in two categories:

- Phosphate rock
- Contained P₂O₅

Australia's EDR of **phosphate rock** almost doubled to 945.4 Mt from 492.1 Mt in 2010. Ninety-three percent of Australia's EDR occurs as sedimentary phosphate rock (phosphorites) in the Georgina Basin at Phosphate Hill, Paradise South and Paradise North in Qld and at Wonarah, Nolans Bore and Ammarroo in the NT. Australia has less than 1% of the world's economic resources of phosphate rock.

Potash is a generic term covering a variety of potassium-bearing ores, minerals and refined products. Potash is not mined in Australia, which has only modest resources by world standards. Australia's fertiliser requirements are met through phosphate rock production and imports of potassium fertiliser. Ongoing exploration in recent years has led to recent published resources for some deposits such as Lake Disappointment, Lake Chandler and Dandaragan Trough/Dinner Hill deposits in WA, in the WA/NT portion of Lake Mackay and in the Karinga Creek Salt Lakes area in the southern NT.

Australia's EDR of **rare earth oxides** in 2011 were 2.03 Mt which increased from 1.83 Mt in 2010. Significant resources of rare earths are contained in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucosene and zircon content. Currently, extraction of rare earths from monazite is not viable because of the cost involved with the disposal of thorium and uranium present in the monazite.

Shale oil resources predominantly occur in a series of sedimentary basins near Gladstone and Mackay and further north near Proserpine in central Qld. Australia currently has no EDR of oil shale, with all resources being assessed as subeconomic. A small-scale technology demonstration Paraho II™ oil shale processing retort near Gladstone, Qld, produced its first crude oil in September 2011.

Australia's EDR of **tantalum** increased by 17% to 62 kt in 2011, ranking Australia the second largest in the world behind Brazil. More than 92% of the EDR are located in WA and are associated with the Greenbushes and Wodgina deposits.

Australia's EDR of **tin** increased slightly (by 6%) to 243 kt in 2011, ranking Australia's resources as the world's eighth largest. Just under 80% of Australia's EDR of tin are contained in the Renison Bell deposit in Tasmania.

Australia's EDR of **tungsten** in 2011 was 376 kt, similar to 2010 levels, ranking it the second largest globally with 11.4% of the world's economic resources. Half of Australia's EDR is contained within the O'Callaghans multi-commodity deposit in WA.

Australia's **uranium** resources are reported in the categories of the international classification scheme for uranium. Reasonably Assured Resources (RAR) that can be produced at costs of less than US\$130 per kilogram (kg) are equivalent to EDR (Australia's National Scheme). Australia's RAR of uranium that can be produced at costs of less than US\$130/kg at December 2011 were estimated to be 1196 kt, which was an increase of 3% on the estimates for 2010. Costs of mining and milling uranium ores have increased during the past few years and, as a result, resources in many uranium mines and deposits are now assigned to higher cost categories compared with the estimates for 2009 and 2010. During 2011, the Honeymoon in situ recovery uranium mine commenced production.

Australia's **vanadium** EDR declined by 14% in 2011 to 1519 kt. This represents approximately 2.5% of estimated global vanadium resources, ranking Australia fourth in the world. The economic impacts of volatile prices and the nature of the vanadium market, which is supplied largely from secondary sources, has a significant impact on Australia's vanadium EDR and the development of Australian vanadium projects. The bulk of Australia's vanadium is located in WA and Windimurra, reopened in 2011, is the only producing vanadium mine.

Australia's total resources of **zinc, lead and silver** rose moderately in 2011. Zinc resources were up by 4%, lead by 3% and silver by 5%. Exploration expenditure for zinc-lead in 2011 was 24% higher than in 2010 at \$84 million. Australia's EDR of zinc, lead and silver in 2011 totalled 68 Mt, 36 Mt, and 88 kt respectively.

Resources to production ratios: Ratios of Accessible Economic Demonstrated Resources (AEDR) to current mine production provide indicative estimates of the resource life. AEDR of most of Australia's major commodities can sustain current rates of mine production for many decades. Resource life based on ore reserves is lower, reflecting a shorter term commercial outlook.

Prior to 2008, there had been a significant trend towards lower AEDR/production ratios for coal and iron ore: a result of major increases in production and reassessment of resources. The decline in iron ore prior to 2008 has been increasingly offset in the past few years by the development of large magnetite iron ore deposits in the Pilbara and mid-west regions of WA. These magnetite resources, which were previously considered to be subeconomic, have been re-assessed as economic.

Commodities with resource life duration of less than 50 years are manganese ore (about 15 years at current rates of production), diamond and gold (35 years) and zinc (45 years).

The severe world financial crisis in late 2008 highlighted the fact that a long resource life for a particular commodity is not a guarantee that such resources will continue to be exploited in Australia. In an increasingly competitive and globalised commodity market, multinational mining companies are continuously seeking mineral deposits that will provide attractive returns on their investment. Such returns are influenced by the quality of the resources (grade and tonnage) as well as environmental, social and political factors, land access and the location and scale of competitor projects. Individual mine projects in Australia will be ranked by multinational companies against the investment returns from other deposits worldwide.

Australia's continuing position as a premier mineral producer is dependent on continuing investment in exploration to locate high quality resources and/or upgrading known deposits to make them competitive on the world market, as well as investment in beneficiation processes to improve metallurgical recoveries.

Introduction

Geoscience Australia and its predecessors have prepared annual assessments of Australia's mineral resources since 1975. The resource data and related information from *Australia's Identified Mineral Resources* provide input into Australian Government policy decisions and programs associated with the minerals sector and sustainable development of resources.

Australia's Identified Mineral Resources 2012 presents estimates of Australia's mineral resources at end of December 2011 for all major and several minor mineral commodities (Table 1). This national minerals inventory is based on published company reports of Ore Reserves and Mineral Resources. The national resource estimates provide a long-term view of what is likely to be mined. National total for the Joint Ore Reserve Committee (JORC) Code Ore Reserves are compiled for each commodity, which provides the industry view of what is likely to be mined in the short to medium term. Mine production data are based on figures from the Bureau of Resources and Energy Economics. World rankings of Australia's mineral resources have been calculated mainly from information in publications of the United States Geological Survey. A summary of significant industry developments also is presented.

National Resource Classification System

The mineral resource classification system used for Australia's national inventory is based on two general criteria:

1. the geological certainty of the existence of the mineral resource, and
2. the economic feasibility of its extraction over the long term.

For a full description of the system see Appendix 2 'National Classification System for Identified Mineral Resources'.

The description of the National Classification System shows how mineral resources reported by companies under the *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (referred to as the JORC Code) are used when compiling national total resources. The classification category Economic Demonstrated Resources (EDR) is used for national totals of economic resources and provides a basis for meaningful comparisons of Australia's economic resources with those of other nations. Long-term trends in EDR for bauxite, black coal (recoverable), iron ore, gold, copper, lead, zinc, nickel, mineral sands and uranium (recoverable) are presented in Figure 1 and the reasons for significant changes in resource trends are noted.

Accessible Resources

Some mineral deposits are not accessible for mining currently because of government policies or various environmental and land access restrictions such as location within National and State parks and conservation zones, military training areas or environmental protection areas, as well as areas over which mining approval has not been granted by traditional owners. Accessible Economic Demonstrated Resources (AEDR), as shown in Table 1, represent the resources within the EDR category that are accessible for mining.

Table 1. Australia's resources of major minerals and world figures as at December 2011.

Commodity	Units	Australia							World	
		JORC Reserves (a) (% of Accessible EDR)	Demonstrated Resources		Inferred Resources (c)	Accessible EDR (d)	Mine Production 2011 (e)	Economic Resources 2011 (f)	Mine production 2011 (g)	
			Economic (EDR) (b)	Subeconomic						
			Para-marginal	Sub-marginal						
Antimony	kt Sb	52 (50%)	106	9	0	204	106	1.6	1800	169
Bauxite	Mt	1895 (33%)	5665	625	1430	1120	5665	69.98	29 000	223
Black coal										
in situ	Mt		71 146	1 374	5 345	79 013				
recoverable	Mt	19 225 (38%)	57 538	822	3 986	57 305	50 656	461(h)	665 000(i)	6 185(i)(j)
Brown coal										
in situ	Mt		49 135	37 465	16 873	121 198				
recoverable	Mt	n.a.(k)	44 219	33 402	15 185	100 664	34 150	66.73(l)	195 000(i)	1044(m)
Cobalt	kt Co	422 (35%)	1204	237	101	1219	1204	3.85(n)	7334	98.35
Copper	Mt Cu	24.2 (28%)	86.7	1.8	0.6	43.9	86.7	0.96	690	16.1
Chromium	kt Cr	0	0	0	0	3450	0	66.1(o)	>147 700	(p)
Diamond	Mc	150.7 (55%)	272.5	0	0	43.5	272.5	7.6	600(q)	141
Fluorine	Mt F	0	0	0.5	0	0.4	0	0	117(r)	3.02
Gold	t Au	4131 (45%)	9153	487	135	4513	9112	258	52 740	2700
Iron										
iron ore	Mt	15 032 (40%)	37 762	1414	1507	61 489	37 762	488	168 762	2814
iron (contained Fe)	Mt Fe	7804 (43%)	18 152	501	736	29 204	18 152	n.a.	81 101	n.a.
Lead	Mt Pb	12.4 (35%)	35.9	3.4	0.2	22.2	35.9	0.62	92	4.6
Lithium	kt Li	506 (50%)	1006	0	0.1	131	1006	11.7(s)	13 036	34(r)
Magnesite	Mt MgCO ₃	37.5 (11%)	330	22	35	836	330	0.644(t)	8750	20.65(r)
Manganese ore	Mt	143 (72%)	197	23	167	313	197	6.96	1646	41
Mineral sands										
Ilmenite	Mt	41.7 (27%)	188.9	30.3	0.03	182.1	156.0	1.277	1235.48	10.98
Rutile	Mt	6.4 (27%)	27.2	0.5	0.06	40.2	23.9	0.474	51.28	0.77(r)
Zircon	Mt	13.8 (34%)	46.6	1.2	0.07	62.1	40.2	0.762	93.98	1.45
Molybdenum	kt Mo	0	167	1220	0.5	562	167	0	10 100	250
Nickel	Mt Ni	7.04 (35%)	20.4	3.5	0.6	18.4	20.4	0.215	76.0	1.81
Niobium	kt Nb	115 (56%)	205	82	0	418	205	(u)	3000	63
Phosphate										
phosphate rock(v)	Mt	280 (30%)	945	445	0	1813	945	(w)	71 000	191
contained P ₂ O ₅	Mt	45 (31%)	148	61	0	282	148	n.a.	n.a.	n.a.
PGE (Pt, Pd, Os, Ir, Ru, Rh)	t metal	0.01 (25%)	4.7	135.3	35.3	148.2	0.4	0.441	66 000	207
Potash	Mt K ₂ O	0	0	13.2	0	11.4	0	0	9500	37
Rare earths (REO & Y ₂ O ₃)	Mt	0.64 (31%)	2.07	0.41	34.48	25.00	2.07	0	114	0.13
Shale oil	GL	0	0	213	2074	1272(x)	0	0	763 139(i)	1.165(i)
Silver	kt Ag	27.8 (32%)	87.9	2.9	0.6	39.9	87.9	1.73	549	23.6
Tantalum	kt Ta	29 (47%)	62	18	0.2	29	62	(y)	131	0.79
Thorium	kt Th	0	0	74.4(z)	0	404.9(z)	0	0	n.a.	n.a.
Tin	kt Sn	119 (49%)	243	65	32	231	243	5.0(aa)	4863	250
Tungsten	kt W	182 (48%)	376	11.1	1.4	107	376	0.015	3300	72
Uranium	kt U	349 (32%)	1196	33	0	589	1082	5.967	3491(ab)	54.610(ac)
Vanadium	kt V	1230 (81%)	1519	10 324	1713	10 544	1519	0	15 000	62
Zinc	Mt Zn	22.8 (33%)	68.3	1.0	0.8	27.0	68.3	1.51	262	12.5

Abbreviations

t = tonne; **L** = litre; **kt** = kilotonnes (1000 t); **Mt** = million tonnes (1000 000 t); **Mc** = million carats (1000 000 c); **GL** = gegalitre (1000 000 000 L); **n.a.** = not available.

Notes

- a. Joint Ore Reserves Committee (JORC) Proved and Probable Ore Reserves as stated in company annual reports and reports to Australian Securities Exchange.
- b. Economic Demonstrated Resources (EDR) includes Joint Ore Reserves Committee (JORC) Reserves, Measured and Indicated Mineral Resources.
- c. Total Inferred Resources in economic, subeconomic and undifferentiated categories.
- d. Accessible Economic Demonstrated Resources (AEDR) is the portion of total EDR that is accessible for mining. AEDR does not include resources that are inaccessible for mining because of environmental restrictions, government policies or military lands.
- e. Source: Bureau of Resources and Energy Economics (BREE).
- f. Sources: Geoscience Australia for Australian figures, United States Geological Survey (USGS) Mineral Commodities Summaries for other countries.
- g. World mine production for 2010, mostly United States Geological Survey (USGS) estimates.
- h. Raw coal.
- i. Source: World Energy Council (WEC). Survey of Energy Resources 2010.
- j. Saleable coal.
- k. There are no JORC code ore reserve estimates available for brown coal.
- l. Source: Victoria's Minerals, Petroleum & Extractive Industries 2010-11 Statistical Review. Victorian Department of Primary Industries.
- m. Source: World Coal Association.
- n. Source: Western Australian Department of Mines and Petroleum.
- o. 96 573 t of chromite expressed as Cr₂O₃ (Source: Western Australian Department of Mines and Petroleum).
- p. World production of 23 Mt of 'marketable chromite ore' as reported by United States Geological Survey (USGS).
- q. Source: USGS Commodity Summaries 2012. Note - world resource figures are for industrial diamonds only. No data provided for resources of gem diamonds.
- r. Excludes USA.
- s. Calculated assuming a grade of 6% Li₂O in spodumene concentrates.
- t. Production for 2010-11 (Source: Queensland Government. Department of Natural Resources and Mines).
- u. Not reported by mining companies.
- v. Phosphate rock is reported as economic at grades ranging from 8.7% to 30.2% P₂O₅.
- w. Phosphate Hill (Queensland) produced 2.49 Mt of phosphate rock in 2011. Christmas Island produced 604 569 t of phosphate rock and 62 410 t of phosphate dust in 2011.
- x. Total Inferred Resource excludes a 'total potential' shale oil resource of the Toolebuc Formation, Queensland of 245 000 GL that was estimated by Geoscience Australia's predecessor, the Bureau of Mineral Resources, and CSIRO in 1983.
- y. Galaxy Resources produced 0.465 kt of tantalum concentrate averaging 3.3% Ta₂O₅ at Mount Cattlin deposit.
- z. Thorium resources reduced by 10 per cent to account for mining and processing losses.
- aa. For all States except WA where actual figures not available.
- ab. Source: Organisation for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) (2011). Compiled from the most recent data for resources recoverable at costs of less than US\$130/kg U.
- ac. Source: World Nuclear Association.

Trends in Australia's Economic Demonstrated Resources of Major Mineral Commodities

The trends in Economic Demonstrated Resources (EDR) for Australia's major mineral commodities have undergone significant and sometimes dramatic changes over the period 1975–2011 (Fig. 1). These changes for each commodity can be attributed to one, or a combination of the following factors:

- increases in resources resulting from discoveries of new deposits and delineation of extensions of known deposits;
- depletion of resources as a result of mine production;
- advances in mining and metallurgical technologies, e.g. carbon-based processing technologies for gold have enabled economic extraction from low-grade deposits which previously were uneconomic;
- adoption of the Joint Ore Reserve Committee (JORC) Code ¹ for resource classification and reporting by the Australian minerals industry and the subsequent impacts on re-estimation of ore reserves and mineral resources to comply with the requirements of the JORC Code. Many companies re-estimated their mineral resources to comply with the JORC Code. The impacts of the JORC Code on EDR occurred at differing times for each of the major commodities; and
- increases in prices of mineral commodities driven largely by the escalating demand from China over the past decade.

Past trends and changes in EDR for a number of Australia's major mineral commodities are discussed below.

Bauxite

Increases in bauxite EDR in 1989 resulted from delineation of additional resources in deposits on Cape York Peninsula ('a' in Fig 1). Decreases in bauxite EDR in 1992 resulted from reclassification of some resources within deposits on Cape York Peninsula to comply with requirements for the JORC Code ('b').

Black Coal

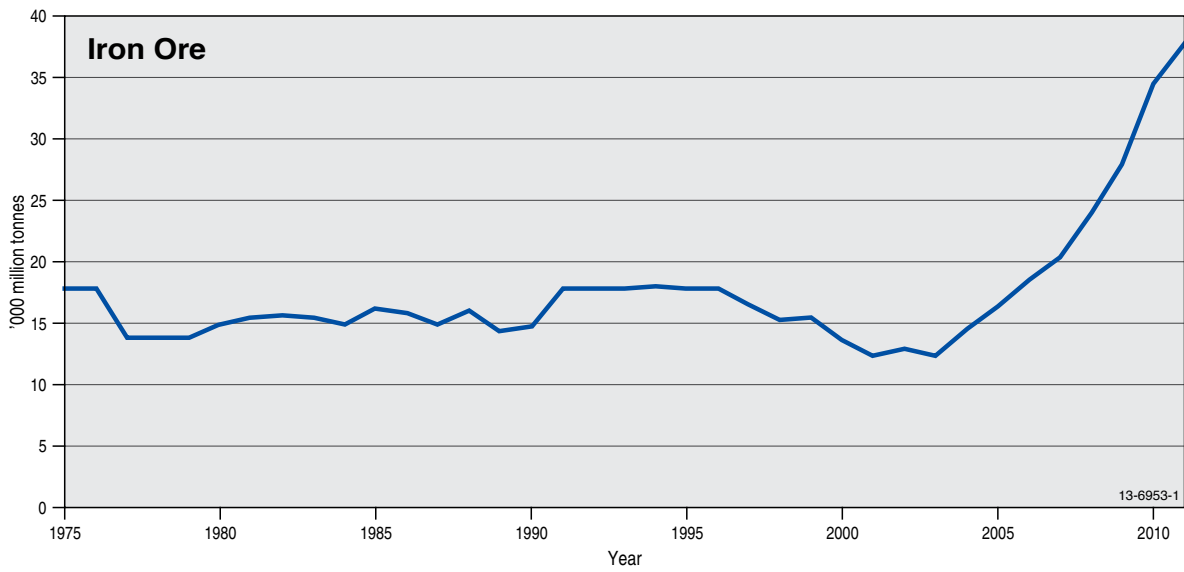
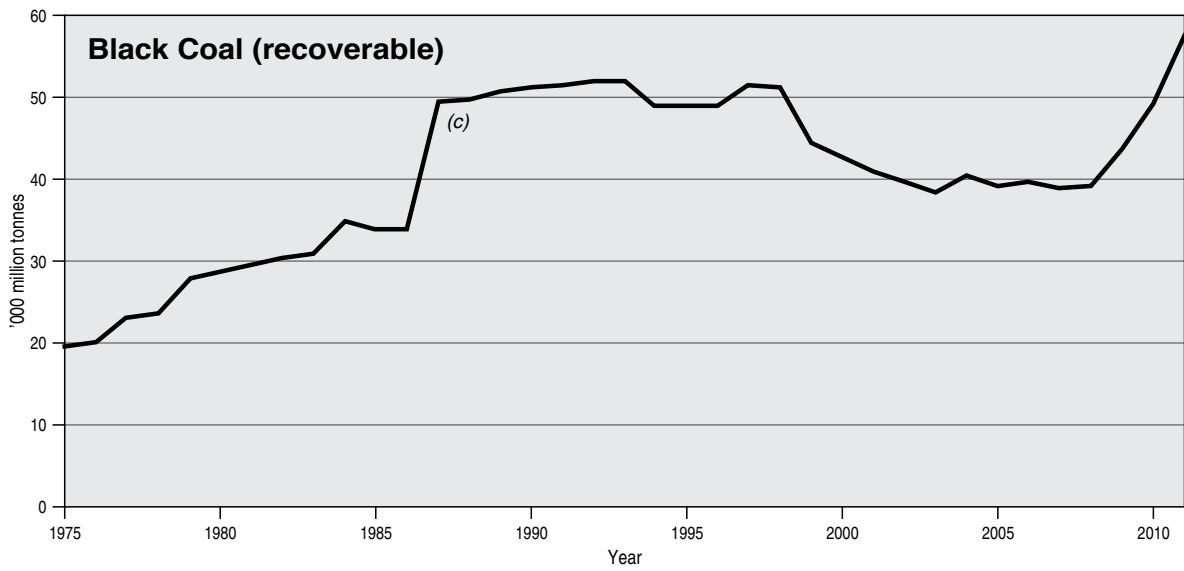
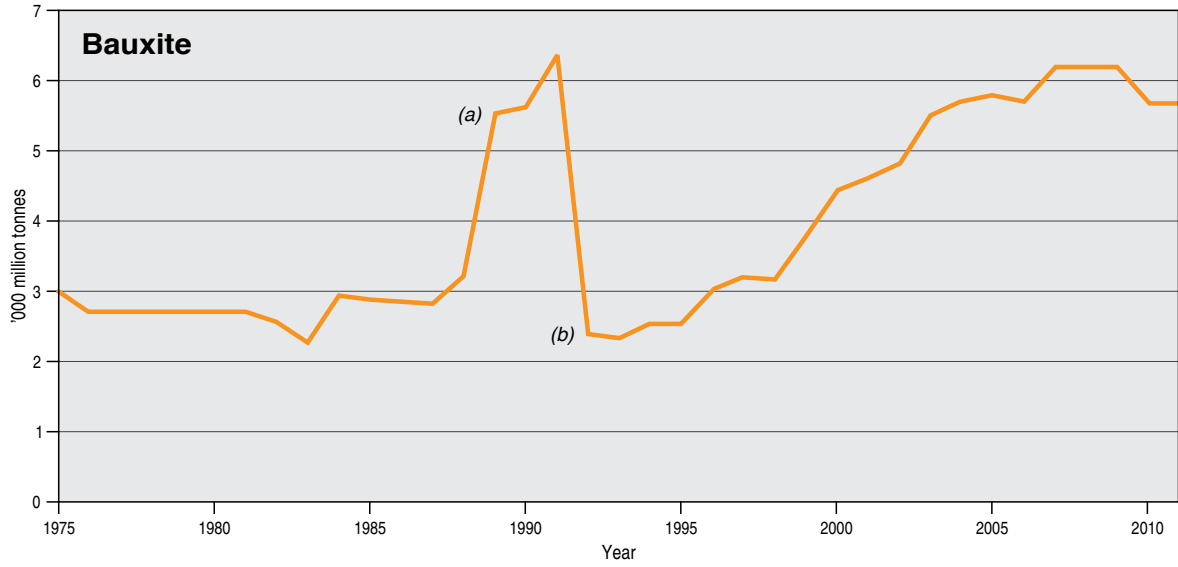
A major reassessment of New South Wales (NSW) coal resources during 1986 by the NSW Department of Mineral Resources and the Joint Coal Board resulted in a large increase in black coal EDR as reported in 1987 ('c').

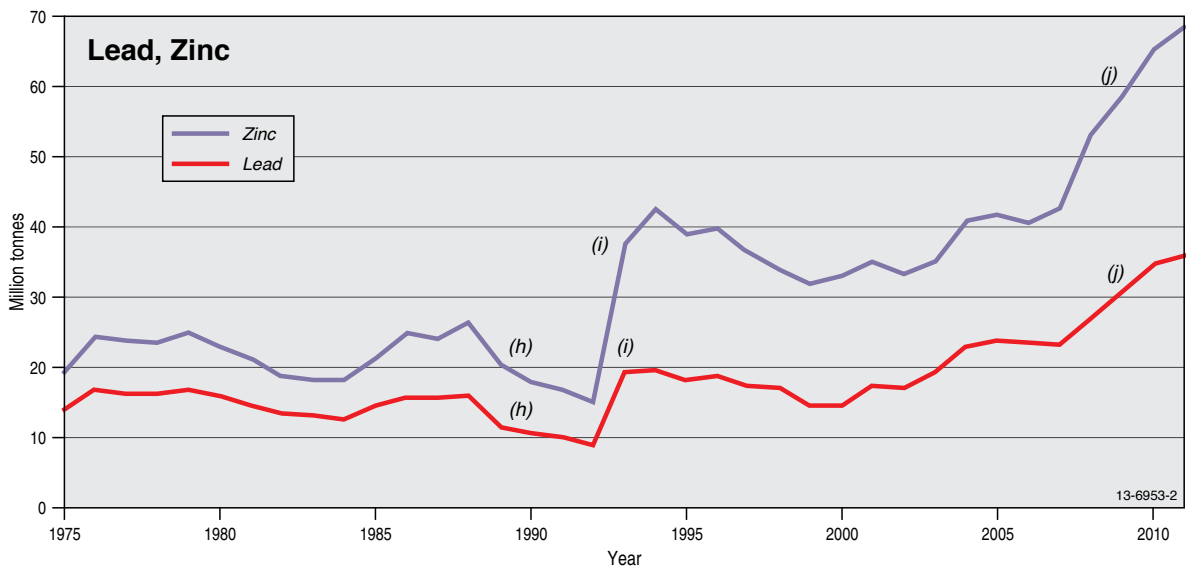
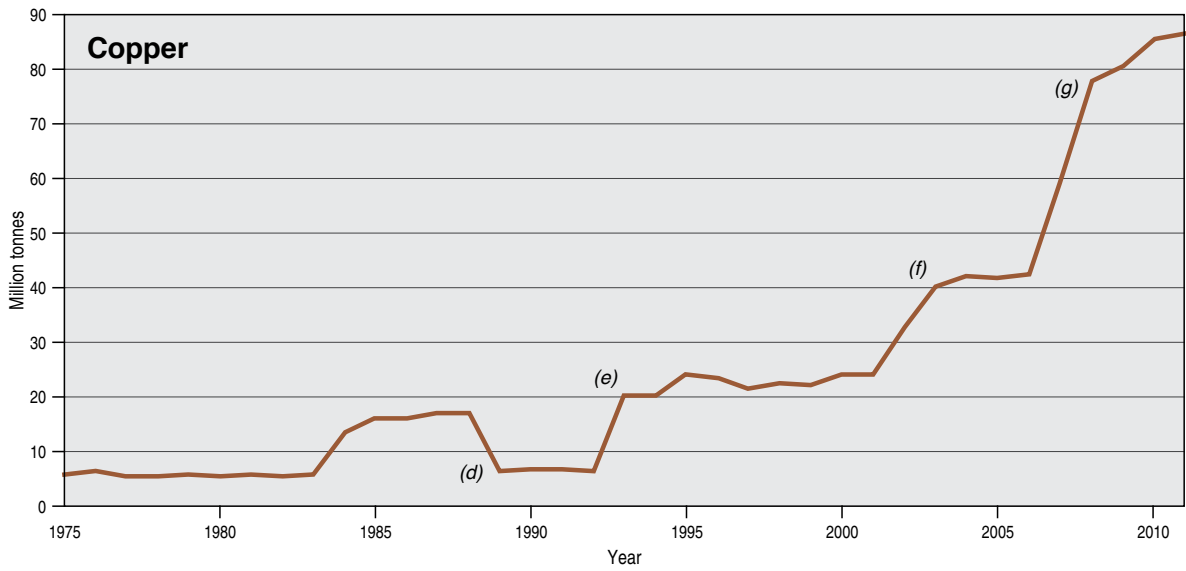
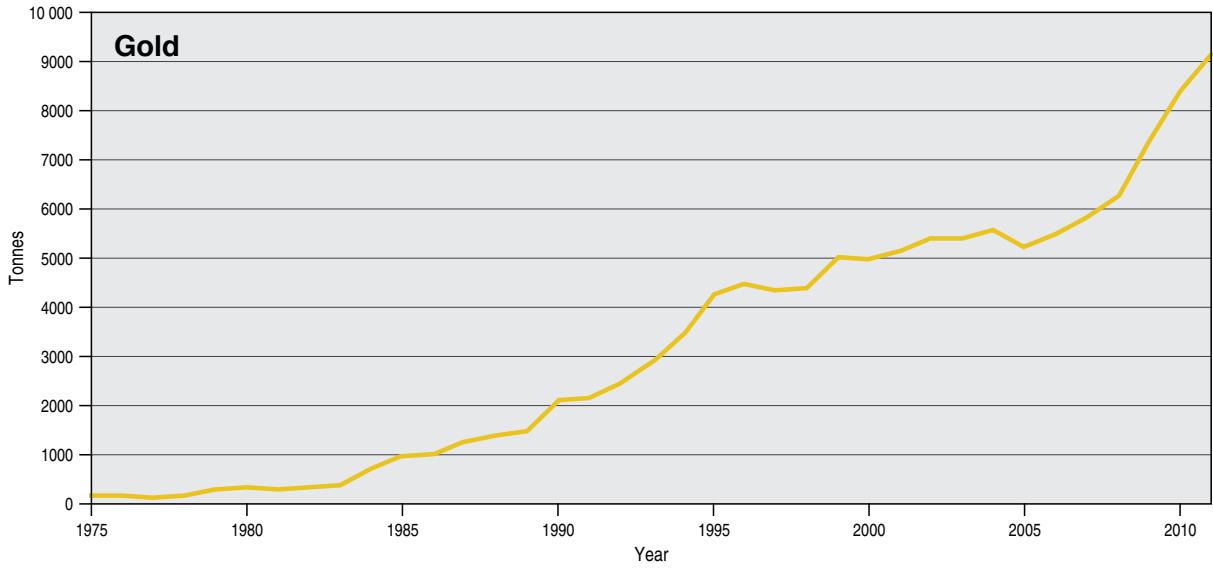
EDR for black coal has declined since 1998 because of the combined impact of increased rates of mine production and mining companies re-estimating ore reserves and mineral resources more conservatively to comply with requirements of the JORC Code. In 2009, black coal EDR increased significantly mainly because of the discovery and delineation of additional resources as a result of high levels of exploration and through reclassification of resources.

Iron Ore

Australia's EDR of iron ore declined from 1994 through 2003 due to the combined impacts of increased rates of mine production and mining companies re-estimating reserves and resources to comply with the requirements of the JORC Code. Post 2003, EDR increased rapidly to 37 800 Mt in December 2011, due to large increases in magnetite resources (including reclassification of some magnetite deposits to economic categories), and increases in hematite resources, mainly at known deposits. Mine production increased rapidly from 168 Mt in 2000 to 488 Mt in 2011.

¹ In 1988, the Australian mineral industry adopted the *Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves* (JORC Code). Many companies first used this code for reporting their mineral resources in 1989. The requirements of the Code differed significantly from the resource classification schemes used by companies prior to 1989.





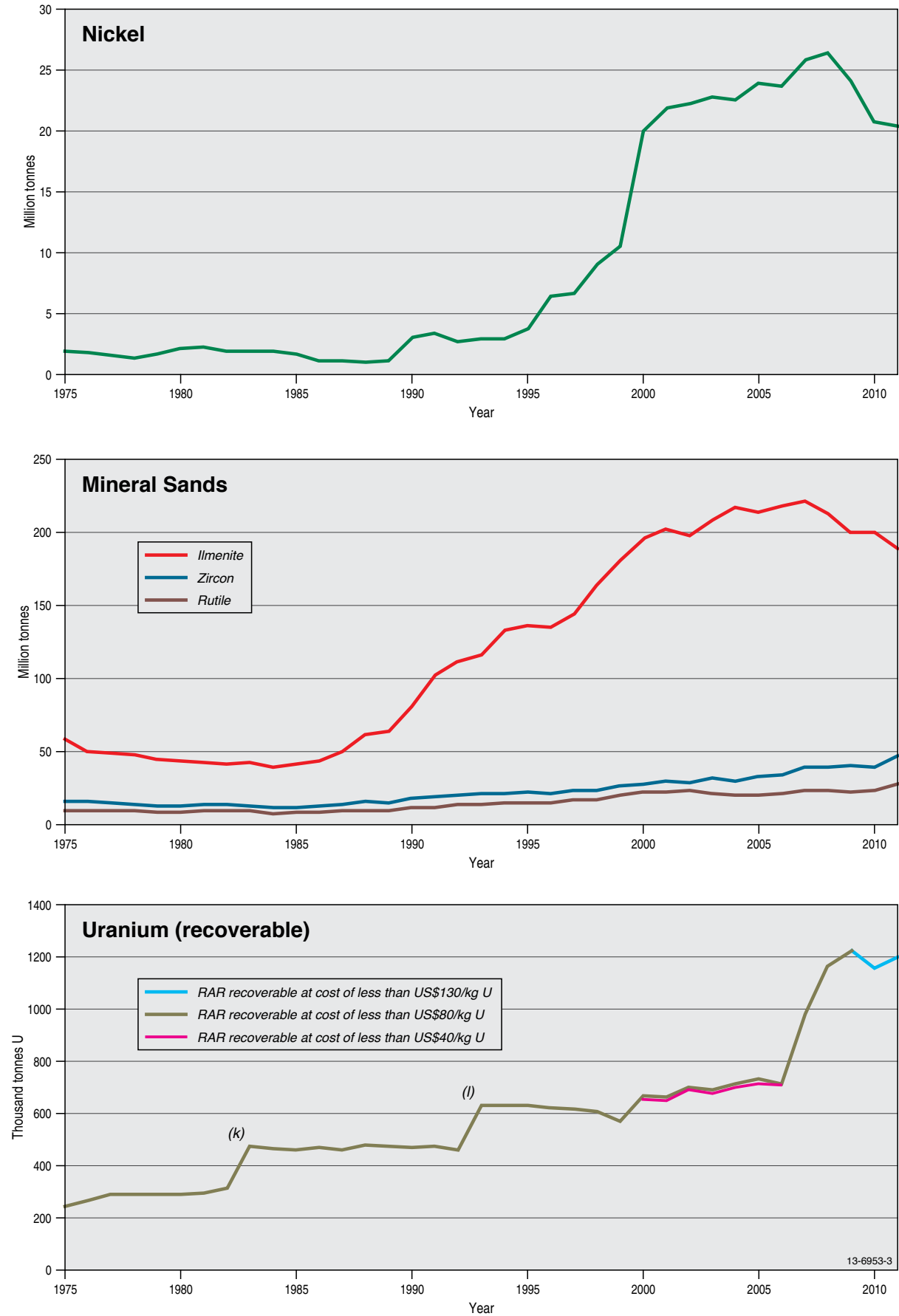


Figure 1. Trends in Economic Demonstrated Resources for major commodities since 1975.

Gold

Gold EDR has increased steadily since 1975 with a clear increase in the rate of growth since 1983. Much of the increase can be attributed to the successful introduction of carbon-based processing technology that allowed the profitable processing of relatively low-grade ore deposits. In addition, the higher than previously prevailing gold prices (denominated in US\$) supported high levels of exploration for gold to the extent that gold accounted for more than half of the total mineral exploration expenditure in Australia for many years. Increased exploration contributed to the increases in EDR.

Copper

Following the adoption of the JORC Code by the Australian mineral industry, many companies first used this code in 1989 for reporting their copper resources. These companies re-estimated mineral resources to comply with the JORC Code which resulted in a sharp fall in Australia's copper EDR in 1989 ('d').

The sharp increase in copper EDR in 1993 resulted mainly from an increase in company announced resources for the Olympic Dam deposit in South Australia (SA). Additional resources were reported also for Ernest Henry in Queensland (Qld), Northparkes (NSW) and other smaller deposits ('e').

Reassessments of copper resources by Geoscience Australia in 2002 and 2003 resulted in further transfers (reclassification) of Olympic Dam resources into EDR ('f'). In 2007 and 2008, copper resources again increased sharply, mainly because of Olympic Dam, where drilling outlined large resources in the southeastern part of the deposit ('g').

Lead, Zinc

The adoption of the JORC Code in 1988 by the Australian mineral industry led to a re-estimation of mineral resources by many companies to align with the JORC Code, and some reassessments of resource data for other deposits by Geoscience Australia's predecessor, the Bureau of Mineral Resources. This resulted in a sharp fall in Australia's lead and zinc EDR in 1989 ('h').

Increases in EDR for lead and zinc in 1993 resulted from the reclassification of paramarginal demonstrated resources into EDR for McArthur River in the Northern Territory (NT) and George Fisher deposits (Qld). Additional resources were reported also for Century and Cannington deposits (Qld) ('i').

Increases in 2008 and 2009 were associated with reassessment of resources at the McArthur River mine, where an expansion from underground to open-cut mining was approved, reassessment of the Dugald River deposit (Qld) for which a new and increased resource estimate was released and reporting of additional resources for George Fisher in Qld ('j').

Nickel

The EDR for nickel increased during the period from 1995 to 2001 by 18.2 Mt. This resulted mainly because of progressive increases in resources of **lateritic deposits** at Bulong, Cawse, Murrin Murrin, Mount Margaret, Ravensthorpe, all in Western Australia (WA), Marlborough (Qld), Syerston and Young (NSW). Australia's EDR of nickel doubled in 2000 (compared to the level at the end of 1999) – this dramatic increase was due to further large increases in resources at the Mount Margaret and Ravensthorpe deposits, and other lateritic deposits in the Kalgoorlie region (WA). In addition, during the period 1995 to 2001 there were increases in resources of **sulphide deposits** at Yakabindie, and the discoveries of the Silver Swan and Cosmos high-grade sulphide deposits (all in WA).

From 2001 onwards, the sharp rises in market prices for nickel led to increased expenditure on exploration and on evaluation drilling at many known deposits. This contributed to further increases in total EDR for sulphide deposits at Perseverance, Savannah, Maggie Hays, Anomaly 1, Honeymoon Well, deposits in the Forrestania area, as well as new deposits at Prospero and Tapinos in WA, Avebury in Tasmania and remnant resources at several sulphide deposits in the Kambalda (WA) region including Otter-Juan and Lanfranchi groups of deposits.

From 2001 onwards, EDR increased at a slower rate because of the absence of further discoveries of lateritic nickel deposits and as a result of increases in resources for some deposits being offset by companies reclassifying their lateritic nickel resources to lower resource categories pending more detailed drilling and resource assessments.

Decreases in nickel EDR from 2009 onwards reflect reclassification of nickel resources in response to the very sharp falls in nickel prices following the 2008-09 global financial crisis followed by only a partial recovery in nickel prices from 2009 onwards.

Mineral Sands

Increases in EDR of **ilmenite** from 1996 to 2003 resulted from discovery and subsequent evaluation drilling of heavy mineral sands deposits in the Murray Basin which include the Gingko and Snapper deposits (NSW), Douglas-Bondi and Woorneck deposits in Victoria, and the Mindarie project (SA). In addition, from 1998 onwards there were progressive increases in resources at mineral sands deposits at Jacinth-Ambrosia and Cyclone in the Eucla Basin embracing parts of SA and WA, in the North Swan Coastal Plain area north of Perth, WA, and the Blackwood Plateau region in WA. The EDR of ilmenite declined after 2007 owing to reclassification of resources to lower resource categories.

Uranium

The majority of Australia's uranium deposits were discovered between 1969 and 1975 when approximately 50 deposits, including 15 with significant resource estimates, were discovered. Since 1975, only another five deposits have been discovered and, of these, only three deposits (Kintyre in the Paterson Province of WA, Junnagunna in Qld and Four Mile in SA) have Reasonably Assured Resources recoverable at less than US\$130/kg U (equates with EDR). As a result, the progressive increases in Australia's EDR for uranium from 1975 to the present were largely because of the ongoing delineation of resources at known deposits.

From 1983 onwards, the Olympic Dam deposit has been the major contributor to increases in Australia's EDR. The large increases shown on Figure 1 occurred:

- in 1983, when initial resource estimates for Olympic Dam and Ranger No. 3 Orebody (NT) were made by the former Australian Atomic Energy Commission ('k');
- in 1993, when further increases in EDR for Olympic Dam and first assessment of resources for the Kintyre deposit were made by Geoscience Australia's predecessor, the Bureau of Mineral Resources ('l');
- in 2000, when increases were due to continuing additions to the Olympic Dam resources; and
- from 2007 to 2009 when a major increase in EDR for Olympic Dam was made after drilling outlined major extensions to the southeast part of the deposit.

Economic resources decreased in 2010 because of higher costs of mining and milling uranium ores. Resources in some deposits were reassigned to higher cost categories than in previous years. In previous years, resources in the cost category of less than US\$80/kg uranium were considered to be economic. As a result of increases in costs and uranium market prices, economic resources in 2010 and 2011 were extended to include resources within the cost category of less than US\$130/kg uranium.

Commodity Reviews



Photo: Aerial view of the Queensland Alumina Limited refinery at Gladstone, Queensland.

Bauxite

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Bauxite is the main raw material used in the commercial production of alumina (Al_2O_3) and aluminium metal globally, although some clays and other materials can be utilised to produce alumina. Bauxite is a heterogeneous, naturally occurring material of varying composition that is relatively rich in aluminium. The principal minerals in bauxite are gibbsite ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$), boehmite ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) and diaspore, which has the same composition as boehmite, but is denser and harder.

Australia is the world's largest producer of bauxite, representing 32% of global production in 2011. The bauxite resources at Weipa in Queensland (Qld) and Gove in the Northern Territory (NT) have average grades between 49 and 53% Al_2O_3 and are amongst the world's highest grade deposits. Other deposits are located in Western Australia (WA) in the Darling Range, the Mitchell Plateau and at Cape Bougainville, of which the latter two have not been developed. The bauxite mines in the Darling Range have the world's lowest grade bauxite ore mined on a commercial scale (around 27-30% Al_2O_3). Despite the low grade, the mines accounted for 23% of global alumina production.

Small deposits of bauxite also occur in New South Wales (NSW), with the largest in the Inverell region where 11 million tonnes (Mt) of low-grade ore has been identified. The richest bauxite deposit in NSW is at Sutton Forest where a small resource of 24 000 tonnes grades at 53.9% Al_2O_3 . These deposits pale in comparison to the large deposits of many millions of tonnes such as Weipa in Qld with 3466 Mt and Gove in the NT with 216 Mt.

More than 85% of the bauxite mined globally is converted to alumina for the production of aluminium metal. An additional 10% goes to non-metal uses in various forms of specialty alumina, while the remainder is used for non-metallurgical bauxite applications. In most commercial operations, alumina is extracted (refined) from bauxite by a wet chemical caustic leach process known as the Bayer process. Alumina is smelted using the Hall-Heroult process to produce aluminium metal by electrolytic reduction in a molten bath of natural or synthetic cryolite (NaAlF_6).

Australia's aluminium industry is a highly integrated sector of mining, refining, smelting and semi-fabrication centres and is of major economic importance nationally and globally. The industry is becoming less vertically integrated, however, owing to the rise of independent smelters, particularly in China.

The Australian industry consists of five long-term bauxite mines, seven alumina refineries, six primary aluminium smelters, 12 extrusion mills and two rolled product plants producing aluminium sheet, plate and foil. The industry in Australia is geared to serve world demand for alumina and aluminium with more than 80% of production exported. Transport, packaging, building and construction provide much of the demand for the metal in Australia.

Resources

The long-term future of Australia's aluminium industry is underpinned by vast resources of bauxite located adjacent to the Gulf of Carpentaria in northern Australia in the regions around Gove (NT) and Weipa (Qld) and in the Darling Range south of Perth (WA). Deposits in these regions rank among the world's largest identified resources in terms of extractable alumina content.

Bauxite deposits identified in the 1960s at the Mitchell Plateau and Cape Bougainville in northern WA are not currently economic to develop, but represent a potential future resource. The lack of large-scale infrastructure and commercial energy supply in the Kimberley region remains a significant hurdle to development of these resources. In addition, the Australian Heritage Council added the West Kimberley (which includes the Mitchell Plateau) to the National Heritage List in August 2011, which has the potential to influence future development proposals.

Economic Demonstrated Resources (EDR) of bauxite totalled 5665 Mt in 2011 (unchanged from 2010). Queensland holds 57%, WA 39% and the NT 4% of Australia's EDR of bauxite.

Australia's Subeconomic and Inferred Resources of bauxite totalled 2055 Mt (unchanged from 2010) and 1120 Mt (up from 950 Mt in 2010), respectively. The bulk of these resources occur in WA.

Accessible EDR

About 95% of bauxite EDR is currently accessible for mining. Some areas within mining leases in the Darling Range in WA are not available for extraction for environmental reasons. The ratio of Accessible Economic Demonstrated Resources (AEDR) to current mine production shows the resource life of existing bauxite operations is around 70 years. The potential exists for further mineral exploration and reserve delineation to extend the current resource life estimate, particularly in the vicinity of existing operations.

JORC Reserves

Approximately 33% of AEDR comprises Joint Ore Reserve Committee (JORC) Code ore reserves as reported by industry. The remainder represents resources assessed by Geoscience Australia as being economically recoverable from measured and indicated categories of mineral resources, as defined under the JORC Code and other classification systems used by companies not listed on the Australian Securities Exchange. The surface expression of bauxite and confidence in lateral continuity of thickness and grade make it possible in certain terrains to classify some Inferred Resources as EDR.

Exploration

Specific data on exploration for bauxite are not available nationally. Because of the scale of existing known resources, much of the exploration effort for bauxite is directed at extending brownfields occurrences close to existing infrastructure.

There are smaller exploration projects, however, occurring away from the five big mines. Examples include Bauxite Resources Ltd and its joint venture partners, which are actively exploring in the Darling Range in WA. During 2011 and 2012, the company drilled a total of 7831 holes for 32 189 metres (m). Another company, Australian Bauxite Ltd, further explored the Binjour Plateau in Qld in 2012, drilling some 200 aircore holes and nine strategically placed diamond drill holes.

Production

Australia was the leading producer of bauxite and alumina globally in 2011 and the fifth largest aluminium producer. Based on Australian Bureau of Agricultural and Resource Economics and Sciences data, production totalled 69.98 Mt (68 Mt in 2010) of bauxite (32% of global production), 18.73 Mt (20 Mt in 2010) of alumina (25% of global production), and 1.95 Mt (1.97 Mt in 2010) of aluminium (5% of global production).

As with other commodities, prices for aluminium reflected the economic volatility experienced as a result of the global financial crisis in 2008-09. After peaking during July 2008, fetching around US\$3100/tonne, prices reached their lowest point of US\$1300/tonne in late 2008. Prices during 2011 and 2012 ranged from a high of US\$2600/tonne in June 2011 to a low of US\$1800/tonne in August 2012.

The export value of each commodity for 2011 was bauxite \$286 million (\$205 million in 2010), alumina \$5320 million (\$5232 million in 2010) and aluminium \$4100 million (\$4172 million in 2010), leading to a total export value of \$9706 million (\$9608 million in 2010).

The economic significance of value adding or first-stage manufacturing to secure enhanced export value is demonstrated through the high values compared to lower volumes for alumina and especially aluminium, and the large volume and relatively small value for bauxite.

World Ranking

According to United States Geological Survey, world bauxite resources are estimated at 29 000 Mt. Australia's demonstrated bauxite resources of 5665 Mt rank second in the world after the Republic of Guinea (7400 Mt), and ahead of Brazil (3600 Mt), Vietnam (2100 Mt), Jamaica (2000 Mt) and India (900 Mt).

Industry Developments

Gove (NT): The Gove bauxite mine and refinery on the western side of the Gulf of Carpentaria is operated by Pacific Aluminium, a subsidiary of Rio Tinto Ltd. Gove has bauxite resources of 216 Mt of which 170 Mt are JORC Code compliant reserves at 49.4% Al₂O₃. The Gove refinery processed 7.246 Mt of bauxite to produce 2.549 Mt of alumina in 2011, compared to 7.190 Mt of bauxite for 2.473 Mt of alumina in 2010.

In 2012, Rio Tinto raised concerns about the future of the Gove refinery as a result of high electricity costs caused by the reliance on diesel power generation and began negotiations with the Northern Territory Government for a long-term gas supply. Rio Tinto also proposed that the Federal Government underwrite the construction of a gas pipeline to the refinery. In November 2012, the Federal Government indicated its support for the construction of the pipeline and the NT Government announced on 11 February 2013 that it had negotiated a 10-year gas-supply deal for the Gove operation. Rio Tinto subsequently committed to keeping the alumina refinery operating.

Weipa (Qld): Weipa, on western Cape York Peninsula, has reserves of 1554 Mt of bauxite at an average grade of 52.8% Al₂O₃ plus additional resources of 1922 Mt at 51.3% Al₂O₃.

In July 2011, the Queensland Government released the Environmental Impact Statement (EIS) for the South of Embley project. The project will result in Rio Tinto extending its bauxite mining south of its current operations at Weipa, and constructing new infrastructure including a power station, processing plant and ship-loading facilities. The Queensland Coordinator General approved the project in May 2012 and in November 2012, Rio Tinto released its draft Commonwealth EIS for the South of Embley project. The project is expected to extend operations at Weipa by up to 40 years.

Binjour (Qld): In October 2011, Australian Bauxite Ltd announced a maiden resource for the Binjour deposit, 110 kilometres (km) southwest of Bundaberg, of 16.8 Mt at 44.2% Al₂O₃. In June 2012, the company increased the resources to a total of 24.5 Mt at 44.1% Al₂O₃. The Binjour bauxite unit is a distinct and predictable layer averaging 6 m thickness, but subject to contamination by silica gel in veinlets. The company claims the silica is easily removable by washing and is continuing to explore the deposit.

Aurukun (Qld): The Queensland Government currently holds the rights to the bauxite resource at Aurukun in Cape York. In November 2012, the state government announced that it was seeking expressions of interest for the development of the mine, stating that proponents must be able to demonstrate experience in developing and managing mines and associated infrastructure and have experience in working with indigenous communities and traditional owners. However, it is not a requirement that the developer establish a refinery at the site.

Other bauxite tenements in the Aurukun region were owned by Callabona Uranium Ltd, which sold its interests to McKay Brook Resources Pty Ltd in October 2011.

Pisolite Hills (Qld): In 2010, the Queensland Government's Wild Rivers Legislation led Cape Alumina Ltd to review and declare uneconomic its plans for the Pisolite Hills bauxite mine and port project, 50 km northeast of Weipa on Cape York. However, in October 2012, the newly elected Queensland Government declared the Pisolite Hills project to be a Significant Project. The company is completing the technical and environmental studies required for an Environmental Impact Statement and is consulting with traditional landowners. In 2008, the company had referred the project to the Commonwealth Government for assessment under the Environmental Protection and Biodiversity Conservation Act 1999 and it was determined to be a "controlled action".

The Pisolite Hills resource is estimated at 134.6 Mt of bauxite with the potential to yield up to 7 Mt per annum of dry-product bauxite over a 15 year mine life.

Bauxite Hills (Qld): Cape Alumina Ltd also has mine and port project located on western Cape York at Bauxite Hills, 95 km north of Weipa. In December 2012, the company completed a pre-feasibility study that confirmed the technical and economic feasibility of a mine producing 5 Mt per annum of bauxite over 10 years. Bauxite Hills has an Inferred Resource of 64 Mt. The company is focussing on the larger Pisolite Hills project but expects that there will eventually be significant synergies between the two projects, such as a shared beneficiation plant and other facilities.

Felicitas (WA): In June 2012, Bauxite Resources Ltd announced an initial resource for the Felicitas bauxite deposit in the Darling Range of WA totalling 73.3 Mt at 39.2% Al₂O₃. The bauxite horizon is between 2 and 16 m thick and additional drilling is planned with a view of adding to the resource base. The deposit is part of a joint venture between Bauxite Resources and Yankuang Group.

Cardea 3 (WA): In November 2011, Bauxite Resources Ltd announced that a mineral resource estimate was completed for the Cardea 3 bauxite deposit in the Darling Range. Total resources amount to 17.8 Mt at 41.2% Al_2O_3 and expansion drilling is planned. The deposit is subject to two separate joint ventures with HD Mining and Investment Pty Ltd (representing the Shandong Provincial Bureau of Geology and Mineral Resources) and Yankuang Group.

Ceres (WA): In July 2012, the HD Mining and Investments Ltd and Bauxite Resources Ltd joint venture announced an Inferred Resource of 15 Mt at 40.9% Al_2O_3 for the Ceres bauxite deposit near Williams in the Darling Range. The company regards this as an excellent result as it opens up the possibility of the Williams area becoming a new bauxite centre. Additional drilling is planned for the future.

Huntley and Willowdale (WA): Alcoa of Australia Ltd, which is the Australian operator for Alcoa Worldwide Alumina and Chemicals, the joint venture between Alumina Ltd and Alcoa Inc, operates two mines, Huntley and Willowdale, on its mining lease 75 km southeast of Perth in the Darling Range. Huntley, opened in 1976, is the world's largest bauxite mine. The annual mining rate at Huntley exceeds 23 Mt and the rate at Willowdale is approximately 10 Mt, with the mining lease valid until 2044. The mines supply bauxite to the Pinjarra and Kwinana alumina refineries.

Despite both Alcoa Inc and Alumina Ltd being publically listed companies on the Australian Stock Exchange and elsewhere, neither publishes resource figures.

Worsley (WA): The Worsley mine and refinery is located in the Darling Range and is operated as a joint venture between BHP Billiton Ltd, Japan Alumina Associates (Australia) Pty Ltd and Sojitz Alumina Pty Ltd. The mine has bauxite resources of 980 Mt. The refinery produced almost 3.4 million tonnes of alumina during the 2011-12 financial year.

Black Coal

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Coal is a sedimentary rock formed from vegetation which has been altered by temperature and pressure over millions of years. The term black coal as used in Australia consists of anthracite, bituminous and sub-bituminous coals and ranges in age from 140 to 225 million years old. The higher rank black coals are mainly used as a fuel in the generation of electricity (thermal coals) and to produce coke (metallurgical or coking coals) for the iron and steel making process. Black coal is used also in other metallurgical applications, cement manufacturing, alumina refineries, paper manufacture and a range of industrial applications. Black coal occurs in all States and the Northern Territory (NT), but Queensland (Qld) with 59%, and New South Wales (NSW) with 26% have the largest share of Australia's total identified resources. Queensland (53%) and NSW (45%) are also the main producers of black coal. There are locally important coal mining operations at Collie in Western Australia (WA), Leigh Creek in South Australia (SA) and in the Fingal Valley and at Kimbolton in Tasmania (Tas). In Australia, about 79% of black coal is produced from open-cut mines.

Resources

A major review of Australia's black coal resource inventory was undertaken for the December 2010 national resource assessment. Continued analysis of the 2010 coal resource data identified additional resource data and an inconsistency in the processing of some 2010 data held in Geoscience Australia's database. Consequently a revised 2010 black coal resource inventory was prepared and is shown in Table 2.

Table 2. Australia's recoverable resources of black coal as at December 2010 (revised).

Black Coal	JORC Reserves (% of Accessible EDR)	Demonstrated Economic (Mt)	Demonstrated Paramarginal (Mt)	Demonstrated Submarginal (Mt)	Inferred (Mt)	Accessible EDR (Mt)
In situ		65 749	1 492	5 405	78 691	
Recoverable	17 335 (36%)	49 188	926	4 014	58 231	48 188

Australia's Recoverable Economic Demonstrated Resources (EDR) as at December 2011 (Table 3) rose by 17% to 57 538 million tonnes (Mt) while in situ EDR rose by 8% to 71 146 Mt. Queensland (61%) and NSW (36%) had the largest share of recoverable EDR in Australia. The Sydney Basin in NSW (30%) and the Bowen (35%), Surat (11%) and Galilee (8%) basins in Qld had the largest shares of recoverable EDR in Australia.

In 2011, estimates of Australia's recoverable Paramarginal Demonstrated Resources fell by 11% to 822 Mt, mainly because the reclassification of some resources to the EDR category. There was a 1% reduction in recoverable Submarginal Demonstrated Resources to 3986 Mt.

The level of Inferred Resources was little changed in 2011. In situ Inferred Resources rose by less than 1% to 79 013 Mt while recoverable Inferred Resources fell by 2% to 57 305 Mt.

Table 3. Recoverable resources of black coal in States and Northern Territory at December 2011.

State	JORC Reserves (% of Accessible EDR)	Demonstrated Economic (Mt)	Demonstrated Paramarginal (Mt)	Demonstrated Submarginal (Mt)	Inferred (Mt)
New South Wales	7 442	20 552	149	35	9 763
Northern Territory					
Queensland	11 547	34 848	580	3	36 120
South Australia		758	40	3 923	9 788
Tasmania		394	3	0	9
Victoria					
Western Australia	236	986	50	25	1 625
TOTAL AUSTRALIA	19 225 (38%)	57 538	822	3 986	57 305

Accessible EDR

Nearly all black coal EDR is accessible with only a relatively small tonnage at Hill River (WA) being quarantined within State Reserves.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves are 19 225 Mt or 38% of Accessible EDR. Included in this tonnage are estimates by Geoscience Australia of reserves of some 1.2 gigatonne (Gt) at operating mines for which no reserves were reported by the mining companies. The estimated resource life of the JORC Code Reserves is about 40 years at the 2011 rate of production.

Exploration

Data published by the Australian Bureau of Statistics (ABS) for coal indicated that exploration expenditure for 2011 totalled \$757.1 million which was more than double the revised data for 2010 of \$361.8 million. Expenditure in Queensland rose by 112% to \$653.8 million or 86% of all Australian coal exploration spending. In New South Wales coal exploration expenditure recovered strongly, after a major reduction in 2010, with an increase of 141% to \$90.1 million while its share of Australian coal exploration spending increased slightly from 11% in 2010 to 12% in 2011. Exploration also occurred in South Australia, Western Australia, Tasmania and Victoria, but ABS does not release details of expenditure in those States. In 2011, coal exploration expenditure contributed 21.2% of the total mineral exploration expenditure in Australia, which was substantially higher than the 14.5% achieved in 2010.

Production and Trade

Australian production of raw black coal in 2011 was 468 Mt (466 Mt in 2009). This yielded 461 Mt of saleable coal, slightly less than the 360 Mt produced in 2010. In 2011, 79% of production of both raw and saleable coal was from open cut mines. Queensland and New South Wales dominate Australian black coal production in 2011 accounting for 56% and 42% respectively of total raw coal production and 51% and 47% respectively of saleable coal production. Black coal was also produced in Western Australia (raw), South Australia (3.8 Mt raw) and Tasmania (0.64 Mt raw) in 2011. Exports of black coal in 2011 were 133 Mt of metallurgical coal, a reduction of 26 Mt over the 159 Mt exported in 2010, and 148 Mt of thermal coal, 6 Mt more than in 2010. The reduced shipments of metallurgical coal were mainly because of adverse weather conditions in Queensland. Australian coal exports in 2011 were valued at \$47 013 million compared to \$42 969 million in 2010 according to the Bureau of Resources and Energy Economics (BREE). BREE forecast that Australia's production of thermal coal will rise to 224.7 Mt in 2011-12 and exports will rise to 162.6 Mt in the same year. Metallurgical coal production is projected to rise to 156 Mt in 2011-12 and exports to rise to 150 Mt.

World ranking

International data for world coal resources and production uses an aggregation of coal by rank which is different to that adopted in Australia. In terms of resources, international estimates refer to anthracite plus bituminous coal as one group and sub-bituminous coal and lignite as a second. Australian statistics for both resources and production refer to black and brown coal where black coal includes anthracite, bituminous and sub-bituminous coal and brown coal refers to lignite. Using the international categories Australia has 9.2% of the world's proven reserves of anthracite plus bituminous coal and 8.6% of the world's proven reserves of sub-bituminous coal plus lignite. In terms of production (all coal) in 2011 Australia accounted for 6.3% of world output.

In terms of the Australian coal categories, it is estimated that Australia has in the order of 6% of the world's economic recoverable black coal resources and ranks fifth behind the USA (31%), Russia (22%), China (14%) and India (8%). Similarly, Australia produced about 6% of the world's black coal in 2010 and ranked fourth after China (51%), the USA (16%) and India (9%).

Industry Developments

New South Wales

In December 2010, Gloucester Coal Ltd was granted environmental and planning approvals for its Duralie Extension Project in the Gloucester Basin. Subsequently Mining Lease ML1646 was granted in January 2011 but the project was delayed by a merit appeal challenge in the NSW Land and Environment Court against the NSW Planning Minister granting environmental approvals for the project. In November, the Court granted approval for the project, but with revised conditions. Implementation of the project will increase production from the Gloucester Basin to 3.5 million tonnes per annum (Mtpa) by 2014, including up to 2 Mtpa of coking coal.

BHP Billiton Ltd announced a US\$400 million expansion of its thermal coal operations in the Hunter Valley. The RX1 project will result in an increase of 4 Mtpa of run of mine thermal coal from the Mount Arthur operation to some 24 Mtpa. The first coal from the expansion is expected in the second half of 2013.

Gujarat NRE received approval from the NSW Planning Assessment Commission for the \$122 million upgrade of existing infrastructure at the NRE No.1 mine at Russell Vale. The approval allows the extraction of up to 1 Mtpa of coking coal from the Bulli and Wongawilli seams for the next three years, the continuation of the coal being transported by truck to the Port Kembla Coal Terminal and upgrades to the existing surface facilities and infrastructure.

Coal & Allied Industries Ltd has a 150 year history in the Hunter Valley as one of the State's major coal producers with current operations at Mount Thorley-Warkworth, Hunter Valley Operations and Bengalla as well as development projects including the Mount Pleasant deposit. In August, the company reported that it had a proposal from Rio Tinto Ltd which could lead to a takeover offer being made to acquire all the outstanding Coal & Allied shares not held by Rio Tinto and Mitsubishi Development Pty Ltd. It was announced in December that all outstanding shares had been acquired and subsequently Coal & Allied was delisted from the Australian Securities Exchange.

Queensland

Queensland's strategic cropping land is subject to competing land uses from the agriculture, mining and urban development. The government's aim is to strike a balance between these sectors. In December 2011, the Strategic Cropping Land Act 2011 and the Strategic Cropping Land Regulation 2011 were approved by the Governor in Council. The new Act and Regulation will commence on 30 January 2012. Under the terms of the legislation proposed new mining developments will be assessed to determine whether they fall into regions defined as Strategic Cropping Land.

Wiggins Island Coal Export Terminal Pty Ltd announced that it had finalised financing and tenure arrangements allowing construction of the 27 Mtpa first stage of the Wiggins Island Coal Export Terminal (WICET) to commence. Stage One is owned by eight coal producers and will be operated by Gladstone Ports Corporation. The eight stage one owners are Aquila Resources, Bandanna Energy, Caledon Resources, Cockatoo Coal, Northern Energy Corporation, Xstrata Coal on behalf of the Rolleston Joint Venture, Yancoal Australia and Wesfarmers Curragh. The eight have executed take or pay agreements with WICET and the first coal shipments are expected from mid-2014. A feasibility study for expansion of the terminal was expected to be completed by the end of 2011. Expressions of interest were received for the expansion in July 2010 from 22 coal producers for more than 176 Mtpa of export capacity.

Once completed, WICET is expected to provide more than 80Mtpa of additional coal export capacity through the Port of Gladstone.

Mine development and expansion decisions by BHP Billiton Ltd and Mitsubishi Development Ltd will see almost 13 Mtpa of metallurgical coal production capacity be added to the alliance's Bowen Basin operations. New mine developments approved were the Daunia mine with a capacity of 4.5 Mtpa and the Caval Ridge mine, which will produce 5.5 Mtpa. In addition, the existing Peak Downs mine will have its capacity increased by 2.5 Mtpa and the life of the Broadmeadow mine will be extended by 21 years with production capacity increased by 0.4 Mtpa to 4.8 Mtpa. There will be an increase also in capacity at the Hay Point Coal Terminal from 44 Mtpa to 55 Mtpa.

The Queensland Government issued a mining lease for the Eagle Downs coking coal project to partners Aquila Resources Ltd and Vale SA. The Eagle Downs deposit is in the Bowen Basin adjacent to BHP Billiton-Mitsubishi Alliance's Peak Downs coking coal mine. The proposed project covers the development and operation of an underground multi-seam longwall mine which will have an average annual production of 4.5 Mtpa from one longwall over the first 10 years of operation.

In December, the Queensland Government announced that it had allocated land south of Mackay for the development of the proposed Dudgeon Point coal export port and for associated infrastructure. The proposed facility will have an annual export capacity of up to 180 Mtpa. Adani Mining and Dudgeon Point Project Management Pty Ltd are the preferred developers of Dudgeon Point and will be responsible for funding the detailed design and construction of the new terminals at Dudgeon Point. Construction is expected to commence in mid-to-late 2012 and operations in 2015-16.

Stanmore Coal Ltd completed a pre-feasibility study (PFS) for The Range Project in the Surat Basin 25 kilometres (km) southeast of Wandoan. The PFS confirmed the project's technical and commercial viability. The study was based on Probable Coal Reserve of 117.5 Mt, which is expected to yield a marketable Coal Reserve of 94 Mt. These reserves are derived from 151 Mt of Indicated Coal Resources and 78 Mt Inferred Coal Resources. The project is proposed to have a 5 Mtpa output from a conventional open cut operation over a mine life of 26 years

South Australia

WPG Resources Ltd reported that Evergreen Energy Inc completed test work on coal samples from the Penrhyn coal deposit which has an estimated Measured and Indicated Coal Resource of 352.4 Mt. Penrhyn is owned by Southern Coal Holdings Pty Ltd, the joint venture company with Evergreen which has the exclusive rights to use Evergreen's coal upgrading technology in Australia for the first 15 Mtpa of product coal. Processing of Penrhyn samples using this technology generated an export-quality thermal coal with a calorific value of at least 5000 kcal/kg which is 25 to 40% higher than the value for raw coal. In addition, Evergreen noted that the process reduced the sodium content by up to 50% and chloride content by up to 70% in the processed coal compared to levels in the raw feedstock.

Western Australia

Attila Resources Ltd reported that drilling at the Talisker North project in the Carnarvon Basin, 650 km north of Perth, intersected a four metre (m) coal seam at 50 m depth. It is approximately 45 km north of the 1980s Talisker coal discovery in the northern Perth Basin. Following this intersection, Attila applied for an additional six exploration licences in the area. The coal is reportedly similar in quality to that in the Collie Basin although Collie coal has lower ash and sulphur. The calorific value of Talisker North coal samples as reported by Attila is 4348 kcal/kg on an as received basis and 7263 kcal/kg on a dry ash-free basis.

Cullen Resources Ltd reached agreement with the private, Singapore-based company Advaita Power Resources Pty Ltd under which Advaita is required to spend \$1.5 million before 31 October 2012 to earn 75% in Cullen's Canning Basin coal tenements. Initial drilling aimed at understanding the region's stratigraphy and exploring for coal in the Lightjack Formation of the Permian Liveringa Group. Coal was intersected and initial analysis suggested that it is potentially a medium rank thermal coal. This drilling is to the north of the Rey Resources's Canning Basin coal project.

Brown Coal

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Brown coal, also called lignite, is a low rank high moisture content coal which is used mainly to generate electricity. In Australia, brown coal occurs in all States and is Tertiary in age (15 to 50 million years old). The Gippsland Basin in Victoria contains a substantial world class deposit of brown coal where seams can be up to 330 metres (m) thick. Currently, brown coal is only mined in Victoria where the open-cut mines at Anglesea, Loy Yang, Yallourn and Hazelwood supply coal to nearby power stations. Brown coal is also mined at Maddingley to produce soil conditioners and fertilisers. Other products from Victorian brown coal are briquettes for industrial and domestic use and low ash and low sulphur char products.

Resources

Continued analysis of the 2010 brown coal resource data identified an inconsistency in the processing of some 2010 data held in Geoscience Australia's database. Consequently a revised 2010 brown coal resource inventory was prepared and is shown in Table 4.

Table 4. Recoverable resources of brown coal in Australia as at December 2010 (revised).

Brown Coal	JORC Reserves (% of Accessible EDR)	Demonstrated Economic (Mt)	Demonstrated Paramarginal (Mt)	Demonstrated Submarginal (Mt)	INFERRED (Mt)	Accessible EDR (Mt)
In situ		49 135	37 192	17 613	121 313	
Recoverable	na	44 218	33 156	15 852	100 806	34 150

Recoverable Economic Demonstrated Resource (EDR) for December 2011 (Table 5) was 44 219 million tonnes (Mt) which was essentially the same as the revised estimate for 2010 shown in Table 4. Recoverable Paramarginal Demonstrated Resources (PDR) rose by less than 1% to 33 402 Mt in 2011 while Subeconomic Demonstrated Resources (SDR) fell by 4% to 15 185 Mt. Recoverable Inferred Resources were less than 1% lower than in 2010 at 100 664 Mt. Victoria accounts for just under 97% of Australia's identified resources of brown coal. Almost 99% of Australia's EDR is in Victoria with more than 90% in the Latrobe Valley.

Table 5. Recoverable resources of brown coal in Australia at December 2011.

State	JORC Reserves (% of Accessible EDR)	Demonstrated Economic (Mt)	Demonstrated Paramarginal (Mt)	Demonstrated Submarginal (Mt)	Inferred (Mt)
New South Wales					
Northern Territory					
Queensland					
South Australia			2 820	246	776
Tasmania			106		
Victoria		43 706	30 111	14 939	98 142
Western Australia		513	365		1 746
TOTAL AUSTRALIA	na	44 219	33 402	15 185	100 664

Accessible EDR

Approximately 78% of brown coal EDR is accessible. Quarantined resources include the APM Mill site, which had a 50 year mining ban applied in 1980. Other quarantined resources include the coal under the town of Morwell and the Holey Plains State Park, both in Victoria. The resource life of the accessible EDR of 34 150 Mt at the 2011 rate of production is more than 500 years.

JORC Reserves

There are no publicly reported brown coal reserves that comply with the Joint Ore Reserve Committee (JORC) Code.

Exploration

The Australian Bureau of Statistics does not report data relating to exploration expenditure for brown coal.

Production

Australian brown coal production for 2010-11 reported by the Victorian Department of Primary Industries was 66.7 Mt. All production was from Victoria with the Latrobe Valley mines of Yallourn, Hazelwood and Loy Yang producing about 98% of Australia's brown coal. Other brown coal is mined at Anglesea for electricity generation for aluminium smelting and at Maddingley.

World Ranking

International data for world coal resources and production uses an aggregation of coal by rank which is different to that adopted in Australia. In terms of resources, international estimates refer to anthracite plus bituminous coal as one group and sub-bituminous coal and lignite as a second. Australian statistics for both resources and production refer to black and brown coal where black coal includes anthracite, bituminous and sub-bituminous coal and brown coal refers to lignite. Using the international categories Australia has 9.2% of the world's proven reserves of anthracite plus bituminous coal and 8.6% of the world's proven reserves of sub-bituminous coal plus lignite.

In terms of the Australian coal categories it is estimated that Australia has in the order of 19% of the world's recoverable brown coal EDR and ranks second behind the USA (20%). Australia produces about 7% of the world's brown coal and is ranked as the fifth largest producer after Germany (16%), Russia (8%), Turkey (7%) and China (7%).

Industry Developments

Brown Coal Innovation Australia (BCIA) funded research and development projects in brown coal low-emissions and product innovation technologies. BCIA's 2011 funding program included:

- Research and development in emerging technologies for the capture of CO₂ at a lower energy and cost penalty compared with existing technologies.
- International collaboration to enable gasification for brown coal-fired power generation thereby reducing CO₂ emissions and lowering generation costs.
- Trials to determine the merits of using brown coal to improve soil health and plant yields.
- Research of processing methodologies to reduce spontaneous combustion of dried or dewatered brown coal.
- Determining the best and most cost-effective solvent absorbent technologies for the capture of CO₂ emissions from brown coal.
- Investigation by the CSIRO Advanced Coal Technology and Exergen Pty Ltd of high efficiency power generation using processed Victorian brown coal in an adapted diesel engine.
- HRL Developments Pty Ltd - Kawasaki Heavy Industries Ltd project on the technical and economic merits of options for production of hydrogen, at both pilot and commercial-scale, from Latrobe Valley brown coal.

Mantle Mining Corporation Ltd reported that it had intersected coal in the first four holes of a 15-hole drilling program at Bacchus Marsh which was aimed at defining an Inferred Coal Resource at the project. The cumulative coal thicknesses intersected in the first four holes were more than 25% greater than was predicted from modelling historic drilling in the area. Analyses of the coal showed that the Bacchus Marsh coal has lower moisture content and higher nett wet calorific values than those of the Latrobe Valley and therefore may be of a higher rank. Mantle also entered preliminary agreements to develop the deposit with Exergen Pty Ltd which has developed a brown coal dewatering technology. Trials on Bacchus Marsh coal confirmed that the technology could result in 56.7% coal moisture being reduced to 9.5% briquette moisture.

Blackham Resources Ltd reported encouraging results from preliminary coal upgrading tests on brown coal samples from the planned open pit area of the Scaddan deposit in Western Australia. They indicated that the coal could be dried to less than 0.01% moisture with an expectation that it would reabsorb 7–8% moisture resulting in a gross wet calorific value of 19.6 megajoules per kilogram (MJ/kg). Blackham finalised a scoping study for the export of Scaddan coal through Esperance. The study examined several options with the two preferred being Option 1 with 8 million tonnes per annum (Mtpa) production shipped through an expanded bulk Port of Esperance with Blackham paying its additional port capital requirements and Option 2 with 8 Mtpa production shipped through an expanded bulk Port of Esperance with an infrastructure group paying additional port capital requirements and Blackham paying an additional tariff to access the third party infrastructure.

The mine plan called for coal production of 480 Mt over 60 years.

Copper

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Australia is a major copper (Cu) producer with mining and smelting operations at Olympic Dam in South Australia (SA) and Mount Isa in Queensland (Qld). Other significant copper producing operations are at Prominent Hill (SA), Northparkes, Cadia-Ridgeway, Cobar and Tritton in New South Wales (NSW), Ernest Henry (Qld), Nifty, Boddington, Telfer and Golden Grove in Western Australia (WA), and Mount Lyell in Tasmania (Tas). Copper and copper alloys are used in building construction, electrical cables and electrical equipment as well as in industrial machinery and equipment. An average car contains more than 20 kilograms (kg) of copper and suburban homes have around 200 kg of copper.

Resources

Australia's total demonstrated resources of copper rose by 1 million tonnes (Mt) in 2011 to 133 Mt, with NSW contributing the most to the increase.

Similarly, Australia's Economic Demonstrated Resources (EDR) of copper rose by 1 Mt to 86.7 Mt, an increase of 1% on the EDR in 2010. South Australia has the largest EDR at 58.2 Mt, which is 67% of the national total. Almost all of the EDR in SA are associated with BHP Billiton Ltd's Olympic Dam deposit, where EDR of 55.4 Mt are slightly higher than in 2010. Ninety-two percent of Australia's total copper EDR is held by 12 companies (Table 6) with the Olympic Dam deposit dwarfing all others. Queensland has 13% of Australia's copper EDR, predominantly in the Mount Isa region. New South Wales has 12%, which is nearly all in the Lachlan Fold Belt and largely at Cadia. The balance of Australia's copper EDR is principally in WA which has 6% of the national total.

Inferred Resources were similarly little changed, rising by less than 1 Mt to 43.9 Mt in 2011. South Australia holds 67% of Australia's Inferred Resources, most of which is at Olympic Dam, followed by Qld with 15%, NSW with 8% and WA with 7%.

Table 6. Ninety-two per cent of Australia's total copper EDR is held by 12 companies.

Company	Key Mines or Deposits	Resources (Mt Cu EDR)	Percentage of Australia's Cu EDR (%)
BHP Billiton Ltd	Olympic Dam	55.4	63.7
Newcrest Mining Ltd	Cadia Valley, Telfer	9.1	10.5
Xstrata Plc	Mount Isa, Ernest Henry	6.6	7.6
Ivanhoe Australia Ltd	Mount Elliott, Osborne, Mount Dore, Starra	1.8	2.1
OZ Minerals Ltd	Prominent Hill	1.6	1.9
Newmont Mining Corporation	Boddington	1.5	1.7
Aditya Birla Minerals Ltd	Nifty, Mount Gordon	1.2	1.4
Rio Tinto Ltd	Northparkes	0.7	0.8
Altona Mining Ltd	Little Eva, Blackard	0.7	0.8
Minerals and Metals Group	Golden Grove, Rosebery	0.6	0.7
Sandfire Resources NL	DeGrussa	0.5	0.6
Cudoco Ltd	Rocklands	0.4	0.5
TOTAL		80.1	92.3

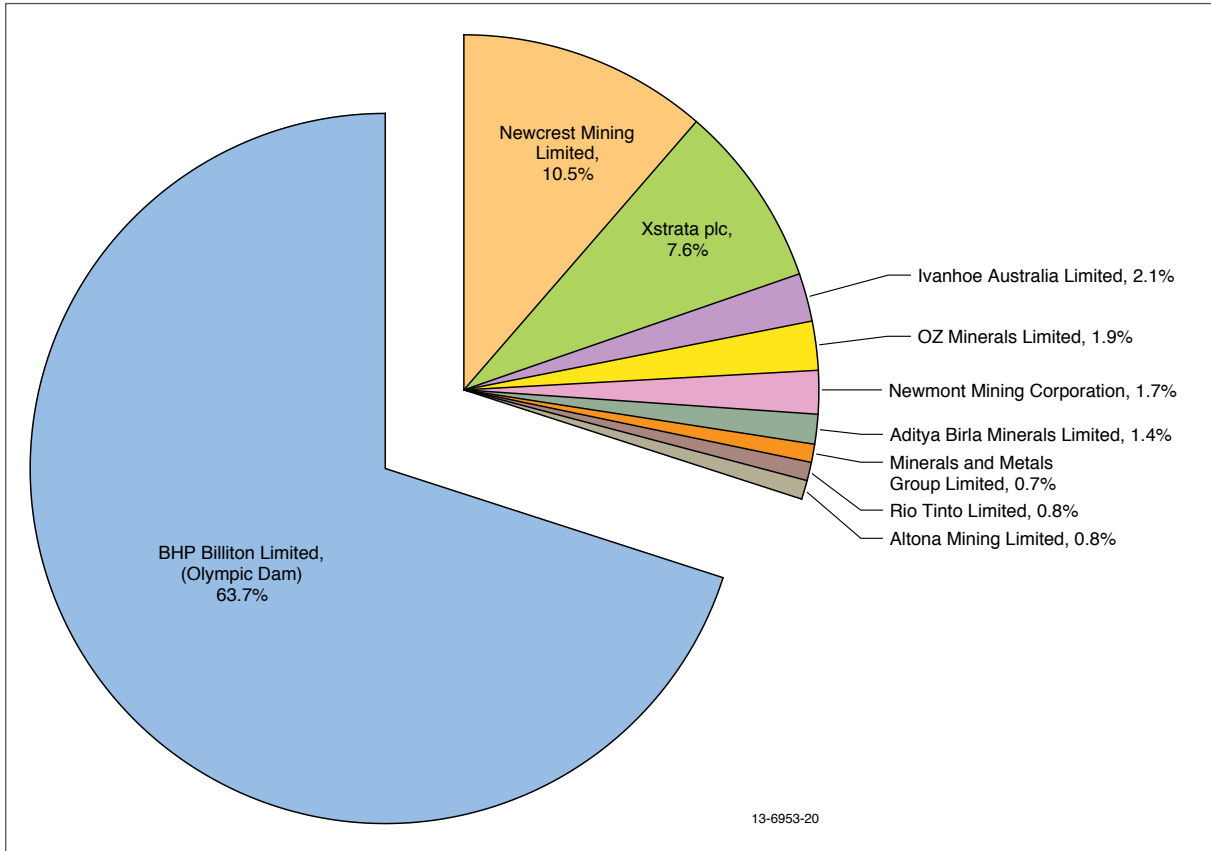


Figure 2. Top 10 company holdings of copper EDR in Australia.

Accessible EDR

All copper EDR is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves account for around 28% of Accessible Economic Demonstrated Resources (AEDR). The remaining AEDR comprise those Measured and Indicated Resources reported by mining companies that Geoscience Australia considers will be economic over the long term. The copper resource life using national AEDR divided by annual production is 90 years, but using the ore reserve and dividing by annual production gives a resource life of around 25 years.

Exploration

Spending on exploration for copper rose by 51% in 2011 to \$396 million. Expenditure in Qld of \$131 million was 33% of all copper exploration. Expenditure in SA of \$130 million represented a further 33%. The main areas of expenditure in Qld were the Mount Isa and Cloncurry districts. In SA, expenditure was in the search for further Olympic Dam style mineralisation in the Gawler Craton. Western Australia had 20% of spending on copper exploration across a range of projects, largely focused on seeking volcanogenic massive sulphide (VMS) ore deposits. New South Wales had about 8%, with the remainder in the Northern Territory (NT) with 4% and around 1% in both Victoria and Tas. Expenditure on exploration for copper made up 11% of all of Australia's mineral exploration expenditure.

Production

In 2011, Australia's mine production of copper totalled 961 kilotonnes (kt) of contained copper, 10% higher than in 2010 (870 kt). In 2011, SA surpassed Qld as the top copper producer with a total of 312 kt, which was 28% more than in 2010 and represented 32% of all Australian production. Olympic Dam and the recently commissioned Prominent Hill

mine produced almost all of SA's output, contributing 20% and 11% respectively of national production. In 2011, Qld produced 305 kt of copper, largely from Mount Isa and Ernest Henry. For a third year, Qld production was significantly down on the historic average of around 400 kt per annum (ktpa) for the years 2000 to 2008. New South Wales produced 177 kt (18%) in 2011, up 19% on 2010, largely from Northparkes, CSA Cobar, Ridgeway, Tritton and Cadia Hill. Western Australia produced 140 kt (15%), down 17% on 2010, mainly from Nifty, Boddington, Telfer and Golden Grove. Tasmania produced 27 kt, down 3% on 2010, mostly from Mount Lyell, but with some from Rosebery.

The value of Australia's exports of copper concentrates and refined copper in 2011 totalled \$8.6 billion, up 14% on the \$7.6 billion in 2010, but holding at 3% of the value of total merchandise exports. The Australian-dollar average copper price for 2011 rose 5% to \$8584 a tonne compared to the average of \$8165 a tonne in 2010. The average copper price in the December quarter of 2011 was \$7407, 15% lower than in the corresponding quarter of 2010. Copper exports in 2011 increased 7% to 904 kt, largely because of the 10% increase in copper production.

Ninety-two percent of Australia's total 2011 copper production from mining of 961 kt is produced by 11 mining companies as shown in Table 7 below. The top four producers account for 66% of mined copper production.

Table 7. Australian mined copper production totalled by company.

Company	Mines	2011 copper production (kt)	Percentage of Australia's 2011 copper production (%)
Xstrata Plc	Mount Isa, Ernest Henry	249	26
BHP Billiton Ltd	Olympic Dam	197	20
OZ Minerals Ltd	Prominent Hill	108	11
Newcrest Mining Ltd	Cadia Valley, Telfer	78	8
Aditya Birla Minerals Ltd	Nifty, Mount Gordon	56	6
Rio Tinto Ltd	Northparkes	50	5
Glencore International Plc	Cobar CSA	45	5
Newmont Mining Corporation	Boddington	31	3
Straits Resources Ltd	Tritton	25	3
Minerals and Metals Group	Golden Grove, Rosebery	23	2
Sterlite Industries (India) Ltd	Mt Lyell	23	2
TOTAL		885	92

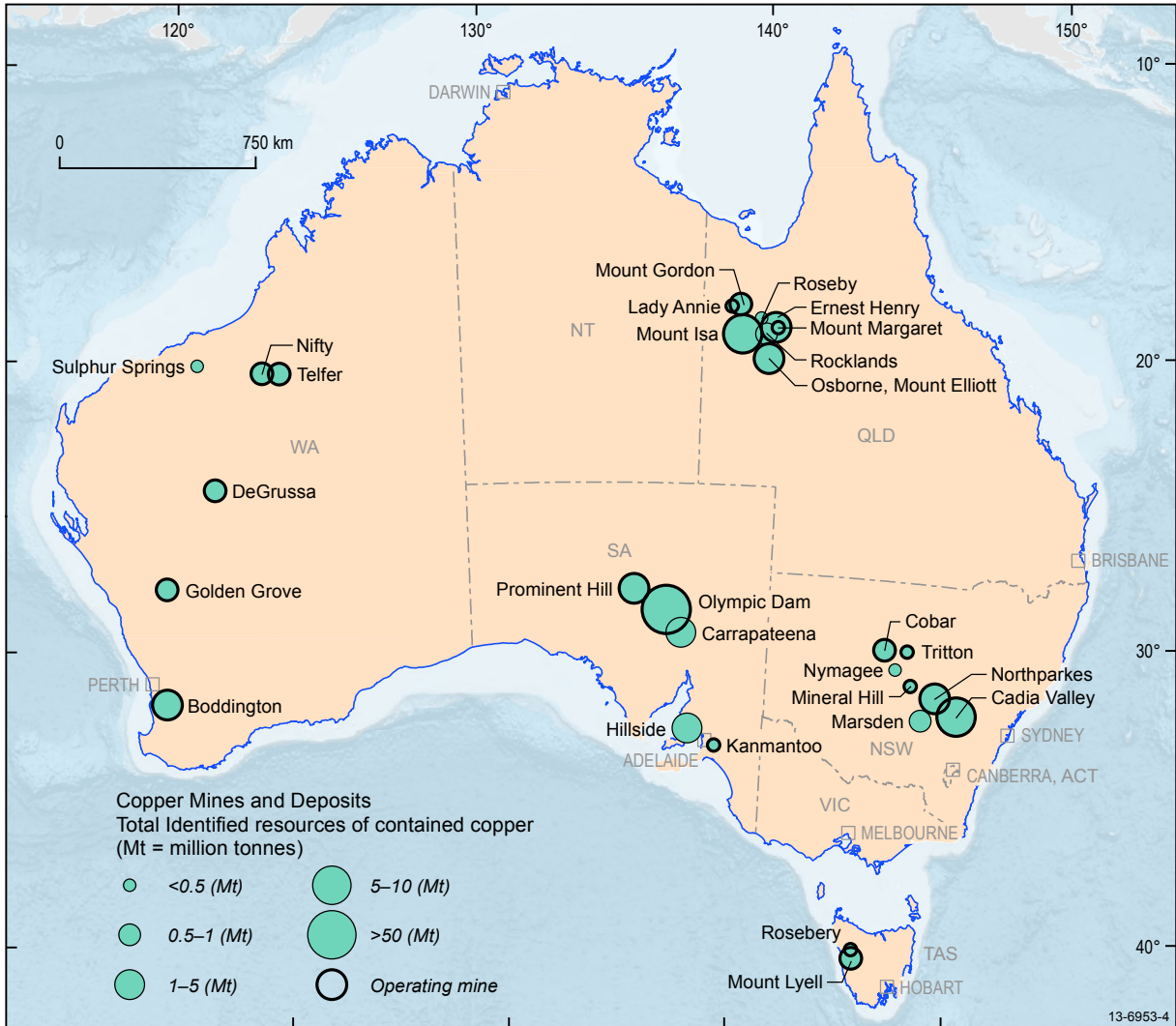


Figure 3. Australian copper mines and deposits with significant resources.

World Ranking

Based on United States Geological Survey (USGS) data for other countries, Australia has the third largest world economic resources of copper (13%) after Chile (28%) and Peru (13%) and ahead of Mexico (6%), the USA (5%), and China, Russia, Indonesia and Poland with 4% each. As a producer, Australia ranks fifth in the world, with 6% of world copper production after Chile (34%), Peru (8%) and China and the USA (both 7%).

Industry Developments

Olympic Dam (SA): BHP Billiton reported that 197 kt of copper cathode was produced from its Olympic Dam mine during 2011. This was close to the nominal capacity of 200 ktpa and 49% more than in 2010 when production was reduced for several months following extensive damage to the Clark Shaft haulage system by a falling ore skip in October 2009. During 2010-11, Olympic Dam reported records for annual material mined and for milling. Metallurgical recoveries were 94% Cu, 72% uranium oxide (U_3O_8), 70% gold (Au) and 65% silver (Ag). Olympic Dam has a current reserve life of 57 years.

On 10 October 2011, the South Australian and Federal Governments approved the Environmental Impact Statement for the proposed open-pit expansion of Olympic Dam to increase production by up to 750 ktpa of copper, 19 ktpa of uranium oxide and 0.8 million ounces (Moz) of gold. Under the proposed \$30 billion expansion, Olympic Dam would become one of the world's largest mines. The expansion would be a progressive development, requiring construction activity over 11 years, generating up to 6000 new jobs during the construction phase, as well as a further 4000 full-time positions and an estimated 15 000 new indirect jobs. However, on 22 August 2012, BHP Billiton announced their decision to investigate a

less capital-intensive design of the open-pit expansion, involving new technologies to substantially improve the economics of the project. Measured Resources at the mine at June 2012 were estimated at 1474 Mt grading 1.03% Cu, 0.30 kilograms per tonne (kg/t) U₃O₈, 0.35 grams per tonne (g/t) Au and 1.95 g/t Ag for the sulphide ore. The sulphide Indicated Resources stood at 4843 Mt grading 0.84% Cu, 0.27 kg/t U₃O₈, 0.34 g/t Au and 1.50 g/t Ag.

Mount Isa and Ernest Henry (Qld): Copper-in-concentrate production in 2011 from Xstrata Plc's Mount Isa and Ernest Henry operations totalled 249 kt, an increase of 7% on 2010. At **Mount Isa**, production was 149 kt of copper in concentrate, a decrease of 6% on the previous year as a result of restricted access to some areas due to localised geotechnical issues and planned major maintenance activities. At Ernest Henry, copper-in-concentrate production increased 34% to 100 kt as the site transitioned from the open pit to underground mining. Ernest Henry open pit operations had closed by the end of 2011 as mining operations reached the final high-grade ore zone of the open pit. Initial underground mine production using the access decline commenced in December 2011. Commissioning of the hoisting operations from the main shaft is scheduled to commence in 2013. The magnetite plant was commissioned in 2011 and sold a total of 259 kt of contained magnetite (Fe₃O₄) between June and December. Xstrata reported cost savings of \$49 million as a result of improved by-product credits from magnetite production at Ernest Henry.

The Mount Isa smelter produced 234 kt of copper anode, 11% more than in 2010. Using anode from the Mount Isa smelter, plus some anode from Xstrata's Altonorte smelter in Chile, the Townsville refinery produced 276 kt of copper cathode, a decrease of 4% on 2010, largely because of a temporary plant shutdown in February after a severe tropical cyclone in North Queensland.

Following a review of a \$3 million, eight-month concept study, Xstrata Mount Isa Mines announced in May 2011 it would expand existing mines, potentially develop new mines, but phase out its Mount Isa copper smelting and Townsville refining operations by 2016 and export mineral concentrates. This would require increased rail and port capacity. Findings from the study indicated the potential to mine and process at least 340 Mt of zinc-lead ore and 130 Mt of copper ore by large-scale open-pit mining at Mount Isa. In August 2011, Xstrata commenced a \$47 million pre-feasibility study (PFS) into the development of the large open-pit zinc-lead-copper mine, potentially extending the life of the combined operations to beyond 2060. The PFS, which is expected to be completed in early 2013, will include new drilling to upgrade resource classification, geotechnical and mine design work, planning for logistics and cost of relocating major infrastructure on site. Other work to be carried out will include metallurgical, environmental, infrastructure and financial studies. Xstrata will also consult with the community to ensure socioeconomic, environmental and community interests are addressed within project planning. Subject to the PFS being approved, Xstrata will progress to a feasibility stage and full environmental assessment in 2013.

Prominent Hill (SA): Located 130 kilometres (km) southeast of Coober Pedy in the Gawler Craton, Prominent Hill produced 108 kt of copper and 160 007 ounces (oz) of gold in 2011. Construction of an underground mine to access the Ankata deposit, located 800 metres (m) away from the Malu open pit, continued throughout 2011, with the first stoping ore from the mine produced in early 2012. On 27 December 2011, during Cyclone Grant, a train carrying 33 sheeted kibbles north from the mine to the Port of Darwin, derailed near the flooded Edith River bridge in the NT spilling up to 1200 tonnes of copper concentrate, valued at roughly \$8 million. In early January NT WorkSafe directed OZ Minerals to remove the concentrate south to SA to allow reconstruction works to proceed. At June 2011, Prominent Hill copper mineral resources were 210.4 Mt grading 1.22% Cu, 0.5 g/t Au and 2.8 g/t Ag, and gold mineral resources were 54.4 Mt grading 0.08% Cu, 1.5 g/t Au and 1.1 g/t Ag.

Cadia-Ridgeway (NSW): Newcrest Mining Ltd's Cadia Valley operations are located 250 km west of Sydney and consist of three gold-copper mines, Cadia Hill, Ridgeway and Cadia East. Copper production in 2011 for Cadia Hill was 20 kt, a reduction of 6 kt on 2010 while Ridgeway copper production was 26 kt, an increase of 9 kt on 2010. Heavy rain events early in 2011 restricted access to the high-grade zone at the base of the Cadia Hill pit which impacted on production. This was compounded in November 2011 when a ground slip in the open pit blocked an access ramp and prevented heavy-vehicle access to the bottom of the pit for the remainder of the year. On both occasions, milling continued with ore feed sourced from lower grade stockpiles. The Cadia Hill pit is nearing completion and has a forecast mine life to early 2013. Three kilometres from the Cadia Hill open pit is the Ridgeway gold-copper mine. The top of the Ridgeway deposit lies approximately 500 m below the surface. The less labour intensive Ridgeway Deeps block cave was ramped up during the June 2011 quarter to its designed annual production rate of 6 Mtpa. Ridgeway production of 9 kt more than in 2010 reflects post-commissioning production at Ridgeway Deeps. Increased block-cave ore production, higher grade ore and higher mill throughput all contributed to this increase.

Adjacent to the eastern edge of the Cadia Hill orebody is the Cadia East deposit which is a porphyry zone of gold-copper mineralisation, extending up to 2.5 km east and around 1.9 km below the surface. Cadia East is one of the world's largest gold deposits, comprising a mineral resource of 2300 Mt grading 0.44 g/t Au and 0.28% Cu containing 33 Moz of gold and 7 Mt of copper. The \$1.9 billion Cadia East project commenced in April 2010 and commercial production levels are expected to be achieved by the end of 2012, with annual production from Cadia Valley operations expected to increase to around 90 kt of copper and 0.8 Moz of gold from the 2016 financial year. The Cadia East project was approximately 80% complete at 30 June 2012. Newcrest's strategic research and development of world-leading, underground bulk-mining technologies has advanced mine caving from early concept studies to full-scale trials for application, notably at both Ridgeway and Cadia East and elsewhere. The Cadia East panel cave will be Australia's largest underground mine and will underpin production from Cadia Valley for at least the next 30 years. In 2011, Newcrest received a favourable ruling by the High Court of Australia in respect of a copper royalties dispute at Cadia Valley, resulting in a reversal of \$11 million of previously expensed royalties.

Northparkes (NSW): Located 27 km north of Parkes, Northparkes mine produced 50 kt of copper and 76 000 oz of gold in 2011. Rio Tinto reported resources for 2011 of 288 Mt with 0.57% Cu and 0.26 g/t Au, with additional reserves of 70.4 Mt with 0.8% Cu and 0.29 g/t Au. A prefeasibility study was underway in 2011 to evaluate the potential for further underground mining and processing operations based on a series of large-tonnage, low-grade areas of mineralisation within the existing mine leases. Named the Step Change Project, it includes 155 km of drilling and current mining and milling operations could be significantly expanded to deliver an ore-extraction rate of 30 Mtpa. This would represent a threefold increase in metal production and more than 20 years of additional mine life. Following the discovery of further ore late in 2012, Rio Tinto extended the \$115 million study and now expects it to be completed in 2013. The project includes developing, with international engineering and technology company Aker Solutions, a tunnel-boring system and commissioning it in 2012, as well as evaluating full-scale prototype trials of additional tunnel-boring machines and a shaft-boring system. Working in combination, these two boring systems have the potential to reduce by 40% the time it takes to construct an underground mine compared to conventional methods.

DeGrussa (WA): Located 900 km north of Perth and 150 km northeast of Meekatharra, DeGrussa has reached production status in a relatively short period of time. Sandfire Resources NL reported an increased resource in May 2011 of 14.3 Mt at 4.6% Cu and 1.6% Au, containing 652 kt copper and 742 000 oz gold. Early-stage, open-pit mining began in February 2012 from a high-grade chalcocite part of the resource that begins 55 m below surface and totals 143 kt of direct shipping ore (DSO) and grades 25.6% Cu and 2.5 g/t Au, containing 37 kt of copper. The ship loading and sale of the first DSO from the open pit mine, containing roughly 30% copper, occurred in May 2012, just under three years from the deposit's discovery in 2009. Sandfire Resources forecasts an annual production rate of 77 kt of copper and 36 000 oz of gold will be underway from both the open pit and underground mine by early 2013.

Mount Gordon (Qld): Aditya Birla Minerals Ltd resumed production at Mount Gordon in 2011 after two years on care and maintenance since 2009 in response to low copper prices. In March 2011, Stage 1 approval was granted which allowed limited mining and production, but the restart was delayed until April because of a shaft collapse after wet weather. Stage 2 approval was granted in May, allowing full mining operations to commence. In October Aditya Birla was fined \$140 000 for a breach in requirements to reduce accumulated water. The Mount Gordon operation has the capacity to mine 1.2 Mtpa of ore with a production rate of approximately 20 ktpa of copper. Production for 2011 was 8.1 kt of copper in concentrate. The Mineral Resource as at March 2012 totalled 97.2 Mt at 1.35% Cu.

Nifty (WA): Production at Nifty for 2011 was 48 kt of copper in concentrate from processing 2.1 Mt of sulphide ore. This decrease of 22% from 2010 production of 61 kt resulted from planned lower ore grades, pastefill failures, equipment availability and technical issues. Aditya Birla Minerals Ltd reported that the pastefill plant had since been modified and that a fleet replacement strategy had begun. Nifty has a processing capacity of 2.3 Mtpa and the concentrator plant has a capacity of 2.5 Mtpa. The Nifty resource was reported in July 2012 as 30.5 Mt at 2.5% Cu using a 1.2% Cu cut-off.

Lady Annie (Qld): Hong Kong listed CST Mining Group Ltd reported production of 18 kt of copper for 2011 from the Lady Annie project, located approximately 120 km northwest of Mount Isa. In May 2011 the company reported a 250% jump in resources at the Anthill deposit, which it believes will add a further two years to the Lady Annie mine life. Further drilling at Anthill, as well as the discovery of the Lady Colleen deposit in late 2011, increased total project resources at July 2012 to 71.9 Mt with 0.67% Cu.

Mount Margaret (Qld): In July 2011, Exco Resources completed the \$175 million sale to the Xstrata Plc subsidiary, Mount Margaret Mining, of its E1 and Monakoff tenements, which formerly were part of the Cloncurry Copper Project.

Both deposits contain open-pit copper mineral resources with completed feasibility studies. Now collectively called Mount Margaret, the E1 deposit with 48.1 Mt of ore is located 8 km east of the Xstrata's Ernest Henry Mining operation and Monakoff is 21 km south. The tenements have a combined resource of 52.1 Mt grading 0.77% Cu and 0.23 g/t Au, representing 401 kt of contained copper and 384 000 oz of gold. Over its five-year life, Mount Margaret will produce around 140 kt of copper, 83 000 oz of gold and 560 kt of magnetite in concentrate, at a rate of around 30 ktpa of copper. The first ore from Mount Margaret was trucked to Ernest Henry for processing in August 2012.

Kanmantoo (SA): In November 2011, Hillgrove Resources reached production status at its Kanmantoo copper mine located 55 km east of Adelaide. During the six-month ramp-up, a broken crown gear slowed production for March 2012 but it increased in April to be in line with projections. At March 2012, resources at Kanmantoo were 32.8 Mt grading 0.8% Cu, 0.15 g/t Au, 2.2 g/t Ag and 132 g/t bismuth (Bi), containing 263 kt of copper. Kanmantoo is forecast to produce 80 ktpa of concentrate, containing 20 kt of copper, 10 000 oz of gold and 180 000 oz of silver. Kanmantoo has a reported mine life of up to 10 years.

Mineral Hill (NSW): In July 2011, Kimberley Metals completed an \$8 million refurbishment of the copper-gold processing plant at Mineral Hill in central western NSW, producing an initial 700 tonnes of copper for 2011. Previously mined by Triako Resources from 1987 to 2005, the current restart of the Mineral Hill operation is based on an initial 10-year mine life. A \$4 million modernisation of the underground infrastructure is facilitating mining, via an existing decline, of the Parkers Hill orebody from 2011 onwards and the SOZ and ESOZ orebodies during early 2013. November 2011 saw a significant resource upgrade to 5.2 Mt containing 61 kt of copper, 83 kt of lead (Pb), 47.5 kt of zinc (Zn), 6.12 Moz of silver, and 222 000 oz of gold. In January 2012, the company, renamed KBL Mining Ltd, reported that copper metal in concentrate production was set to increase to 5400 tpa along with annual production of 100 000 oz of silver and 1500 oz of gold.

Carrapateena (SA): Located 130 km north of Port Augusta and approximately 75 km from the Stuart Highway, the Carrapateena deposit begins 470 m below the surface and mineralisation extends down a further 1000 m vertically. In May 2011, ministerial approval was granted for the US\$250 million acquisition of the deposit by OZ Minerals from RMG Services Ltd and Teck Resources. OZ Minerals estimate construction on the project will begin in mid-2015 after completion of a feasibility study. OZ Minerals has reported that options for mining include block caving, sub-level caving and sub-level open stoping. At October 2012, resources were reported as 292 Mt grading 1.29% Cu, 0.48 g/t Au, 201 parts per million (ppm) U and 5.4 g/t Ag.

Hillside (SA): Rex Minerals Ltd announced in October 2011 that it aims to begin production at Hillside SA by 2015 with the operation processing 15 Mtpa for a minimum of 10 years, yielding an annual production of 70 kt copper, 50 000 oz of gold and 1.3 Mt of iron (Fe) ore. Additional copper-gold-iron ore discoveries adjacent to the known Hillside resources were announced in October 2011 grading from 0.6% to 1.3% Cu, 0.1 g/t to 0.5 g/t Au in a depth range of 27 m to 459 m. The prefeasibility study for Hillside was released in October 2012 with a minimum 15-year mine plan at 70 ktpa production of copper to commence in 2015, in line with the 2011 outlook. The July 2012 Hillside resource stood at 330 Mt at 0.6% Cu, 0.16 g/t Au and 13.7% Fe.

Osborne, Kulthor, Starra Line (Qld): Ownership of the Osborne mine and Kulthor deposit changed from Barrick Gold to Ivanhoe Australia in 2010, for \$17.4 million. In 2011, Ivanhoe Australia reported Measured and Indicated Resources for the Osborne, Kulthor and Starra 276 and Starra 222 deposits totalling 22.3 Mt at 1.08% Cu and 0.87 g/t Au as well as Inferred Resources of 21.4 Mt at 1% Cu and 0.86 g/t Au. At the associated Mount Elliot mine, no ore removal or production was undertaken in 2011. Underground mine development work recommenced at Osborne and Kulthor in March 2011, and has since achieved an annual rate of 1.65 Mt. The project has an initial four-year mine life to 2015, with a targeted mine life in excess of 15 years from potential resource expansions.

Copper production from the Osborne processing complex began in February 2012. The Osborne complex is expected to process approximately 700 kt to 800 kt at 1.5% to 1.7% Cu and 0.7 to 0.9 g/t Au in 2012, increasing to 1500 kt at 1.3% to 1.5% Cu and 0.8 to 1 g/t Au in 2013 and 2014. After closing in 2003, development recommenced at the Starra Line 276 deposit in early 2012 with ore to be processed through the Osborne processing complex. In December 2011, work began on widening the existing Starra 276 decline to enable access by larger haul trucks. Resources remaining within the close-by Starra 222 deposit are being evaluated for potential mill feed for the Osborne processing complex.

Mt Dore (Qld): In September 2011, Ivanhoe Australia announced it would carry out a prefeasibility study for the Mount Dore deposit, which is forecast to begin production in late 2014. Mount Dore contains an Indicated Resource of 70 Mt

at 0.6% Cu and 0.1 g/t Au and an Inferred Resource of 38 Mt at 0.6% Cu and 0.1 g/t Au. The project is forecast to have an initial 10-year mine life at a 3 Mtpa processing rate and a production rate of 19 ktpa of cathode copper.

Rocklands (Qld): In May 2011, CuDeco Ltd reported a Measured, Indicated and Inferred Resource totalling 273 Mt at 0.18% Cu, 0.09 g/t Au and 233 ppm Co. In late October 2011, CuDeco entered into an \$86 million agreement with a private Chinese mining and energy group to fund the Rockland project. In November, a 30-year mine lease was granted for Rocklands by the Queensland Government. Environmental approval was given in April 2012 to build a 3 Mtpa (expandable to 5.5 Mtpa) processing plant to produce 480 ktpa of copper-gold-cobalt concentrate. CuDeco entered into a contract with Sinosteel (one of China's largest State owned corporations) to supply the 3 Mtpa processing plant.

Roseby (Qld): Altona Mining Ltd reported in 2011 that production at Roseby, located 95 km northeast of Mount Isa, is expected to commence in mid-2014. Results from drilling in 2011 upgraded the resources of Roseby deposits - Little Eva, Bedford, Ivy Ann and Lady Clayre. By July 2011, the project had a Measured, Indicated and Inferred resource of 177 Mt grading 0.6% Cu and 0.06 g/t Au for 1.1 Mt of copper and 0.3 Moz of gold. A definitive feasibility study based on the largest deposit, the 108 Mt Little Eva, returned an operation producing 375 kt of copper and 205 000 oz of gold over 11 years. Annual production volumes are estimated at 39 kt of copper and 17 200 oz of gold in concentrates, with ore sourced from both Little Eva and the three smaller deposits.

Sulphur Springs (WA): Located 160 km southeast of Port Hedland, Sulphur Springs was acquired for \$26 million by Venturex Resources Ltd in February 2011 from CBH Resources Ltd as part of the Panorama Project. Venturex promptly began a feasibility study into the development of a centralised processing facility for ore from both Sulphur Springs and other holdings in the Pilbara copper-zinc project. In 2012, Venturex reported that a processing plant originally planned to be built at Whim Creek would be built at Sulphur Springs. It is estimated that the plant will produce 18 kt of copper, 30 kt of zinc and 400 000 oz of silver for a minimum of seven years. At November 2012, Sulphur Spring resources stood at 12.8 Mt grading 1.5% Cu, 4.1% Zn, 0.2% Pb and 17.6 g/t Ag.

Nymagee (NSW): YTC Resources Ltd purchased the Nymagee copper mine in conjunction with the Hera gold deposit 10 km to the south of CBH Resources in 2009 for \$12 million. Nymagee mine, which is 100 km southeast of Cobar, last operated in 1918 with a total production of 422 kt of ore grading 5.8% Cu. In December 2011, YTC released a maiden resource estimate for Nymagee of 8 Mt grading 1.2% Cu, 0.3% Pb, 0.7% Zn and 9 g/t Ag containing 96 kt of copper, 27 kt of lead, 53 kt of zinc and 2.2 Moz of silver. The release also announced that mineralisation remained open to the north and at depth. YTC subsequently reported the discovery of a new zone of massive sulphides 500 m north of the Nymagee mine.

Diamond

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Diamond is composed of carbon and is the hardest known natural substance, although it can be shattered with a sharp blow. It also has the highest thermal conductivity at room temperature of any known material. Diamonds form 150–200 kilometres below the Earth's surface at high temperatures (1050 °C–1200 °C) and pressures (45–55 kilobars). They are carried to the surface within kimberlite and lamproite magmas which intrude through the Earth's crust. These intrusions generally form narrow cylindrical bodies called pipes, but only a very small proportion has significant diamond content. When pipes are eroded, liberated diamonds can accumulate in alluvial deposits and may be found far from their source. This is because their hardness allows them to survive multiple episodes of erosion and deposition.

Current uses for diamond include jewellery, mining and exploration, stone cutting and polishing, computer chip manufacturing, machinery manufacturing, construction and transportation services. A large proportion of industrial diamond is manufactured and it is possible to produce synthetic diamonds of gem quality.

Resources

In the past, natural diamond quality has been subdivided into gem, near-gem and industrial categories. However, recent developments within the diamond industry mean that almost all natural diamonds are now used for jewellery, with only 1.4% of industrial diamonds being non-synthetic according to the United States Geological Survey (USGS). As a result, only total carats are reported here.

Australia's Economic Demonstrated Resources (EDR) decreased by 7% in 2011 for total diamond resources to 272.5 million carats (Mc).

Accessible EDR

All diamond EDR is accessible for mining.

JORC Reserves

The Joint Ore Reserve Committee (JORC) Code reserves account for 55% of Accessible Economic Demonstrated Resources (AEDR). The remaining AEDR comprise those Measured and Indicated Resources reported by mining companies, which Geoscience Australia has assessed as being economic in the long term.

Production

Australia produced 7.6 Mc of diamond in 2011, 2.4 Mc less than in 2010 and about one quarter of that produced during the early to mid 2000s. Production during 2011 was almost entirely from Rio Tinto's Argyle mine, which produced 7.4 Mc. Production at Australia's two currently operating diamond mines, Argyle and Ellendale, fell in 2011 due to difficulties associated with an especially severe wet season and mining of lower grade ore.

World Ranking

As a result of the changes in the reporting of Australia's diamond resources described above, it is not possible to compare Australia's EDR for diamonds with the rest of the world based on USGS figures. In terms of overall production, Australia ranks as the world's seventh largest producer of diamonds by weight, down from fifth largest in 2010.

Industry Developments

Argyle (WA): During 2011, production continued at Rio Tinto's Argyle open cut operation, yielding 7.4 Mc of diamonds, including valuable rare pink diamonds. This figure is 24% lower than 2010 production of 9.8 Mc, reflecting the impact of delays and difficulties caused by high rainfall during 2010-11 wet season together with lower ore grades encountered during the final stages of open cut mining. An additional US\$0.5 billion was approved for development of an underground mine in December 2011 in order to compensate the wet season delays and adverse exchange

rates, bringing the total approved amount to US\$2.1 billion. Production at Argyle is expected to transition from open pit to underground mining by 2015 and is expected to extend mine life to at least 2019 with forecast production of 20 Mc per year. In February 2012, Rio Tinto announced that it had discovered Australia's largest rough pink diamond, weighing 12.76 carats. Rio Tinto is currently undertaking a strategic review of its diamond businesses, including Argyle, which will include exploring a range of options for potential divestment of its assets.

Ellendale (WA): Gem Diamonds continued production from the E9 pipe at Ellendale, with the E4 pipe remaining on care and maintenance. Production from the E9 pipe was 0.12 Mc for 2011, compared with 0.16 Mc produced in 2010. Carat production was lower than expected in 2011 owing to an unusually severe wet season and associated ore processing complications, coupled with a lower than expected grade. The first half of 2012 saw improved carat recovery as a result of mining operations continuing during the wet season and modifications to the diamond processing plant. An average price of US\$731 a carat was achieved in 2011, compared to US\$475 a carat in 2010. Rare fancy yellow diamonds achieved an average price of US\$4409. Other commercial diamonds achieved an average price of \$188 a carat in 2011. Current mine life at the E9 pipe is relatively short, with approximately 18 months remaining based on the current mine plan and resource estimate. A resource extension program, intended to better define the diamond resource at Ellendale, was suspended in 2011. Gem Diamonds announced in November 2011 that it was conducting a strategic review into its diamond assets at Ellendale and on 3 December 2012 it was announced that the Ellendale diamond mine had been sold to Goodrich Resources.

Venus Smoke Creek (WA): Following announcements of an initial Inferred Resource of 21.5 million tonnes containing 6 Mc of diamonds in 2011, Venus Metals ordered and commissioned a modular diamond processing plant in late 2011 to evaluate the diamond resource at Smoke Creek. Processing of stockpiled diamond-bearing gravels commenced in mid-2012, with preliminary assessments indicating a high overall diamond quality. By September 2012, 14 samples totalling 2326 tonnes of gravel had been processed, yielding 550 diamonds, with the largest stone weighting 1.46 carats. Reported grades range from 0.167 to 3.219 carats per hundred tonnes, significantly below the initial estimated average grade of 28 carats per hundred tonnes and at variance with work undertaken by Argyle Diamond Mines during the 1980s and 1990s. Venus Metals is currently undertaking an audit to determine the cause of this discrepancy with the possibility remaining for higher diamond grades being identified.

Merlin (NT): Following the completion of prefeasibility production trials during 2010, a contract for a definitive feasibility study was awarded in August 2011. Studies aimed at re-establishing mining at Merlin were the focus of activity during 2012. The feasibility study has focused on hydraulic mining methods to extract the ore, which lowers the level of capital required and operational expenditure. The scope of this study was expanded to include an examination of borehole mining of deep kimberlite ore in mid-2012. North Australian Diamonds aims to begin mining at Merlin in early 2013. In addition to feasibility studies, a 3000 metre exploration drilling program at Merlin commenced in October 2012 to test geophysical and geochemical anomalies.

Borrooloola (NT): A bulk sampling program commenced at Borrooloola in September 2011 to test the potential of diamond-bearing gravels. Bulk sampling of three of the five targeted test areas (approximately three tonnes of material) yielded 22 diamonds with a total weight of 1.09 carats. Further assessment of the remaining two test areas is expected to commence following the wet season.

Gold

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The principal uses for gold (Au) are as an investment instrument for governments, central banks and private investors, with jewellery accounting for most of its annual usage. The main industrial use of gold is in the electronics industry, which takes advantage of gold's high conductivity and corrosion-resistance properties and small amounts are present in most modern electronic devices. Gold is used also in dentistry because gold alloys are strong, resistant to tarnishing and easy to work.

Demand for gold has exceeded world mine production for many years and has necessarily relied on recycling, sales by investors and, until recently, sales by central banks. Over much of the past two decades the central banks have sold down their stocks of gold. However, since early 2010, these banks have become net purchasers of gold to augment their reserves. The World Gold Council has noted that, in particular, the central banks of many emerging nations are maintaining a high percentage of their reserves in gold.

The monthly gold price throughout 2011 started the year at US\$1327 an ounce (oz) and finished at US\$1531/oz, peaking briefly in August at US\$1813/oz. The monthly gold price has been in a long-term upward trend since 2001. The gold price increased by about 80% in the 2001-05 period (from around US\$260/oz to just over US\$490/oz; Fig. 4), before increasing more rapidly to around US\$970/oz at the beginning of the Global Financial Crisis (GFC) in early 2008. During the course of the GFC, the price receded to around US\$800/oz before regaining to around US\$900/oz by January 2009. From August 2009, the price resumed its steep ascent gaining a further US\$910/oz to peak at about US\$1810/oz in August 2011, or nearly doubling in only two years. With the re-emergence of the Euro-zone and other debt crises in 2011, the rise in the price of gold was again arrested, settling to US\$1531/oz in December 2011, before re-adjusting to around US\$1700/oz by mid 2012. During 2011, the exchange rate between the Australian and the US dollars has fluctuated between 0.97 and 1.04, yielding similar prices for the commodity in either currency. In summary, the gold price has increased about US\$1440/oz since 2001 or around 650% in only 10 years. The sustained higher gold prices through 2010 and 2011 have coincided with expanded mining operations, the upgrading of mills and renewed operations at mines previously on care and maintenance, while exploration has been particularly focussed on re-assessing old mining centres with the view to re-establishing production in the short term.

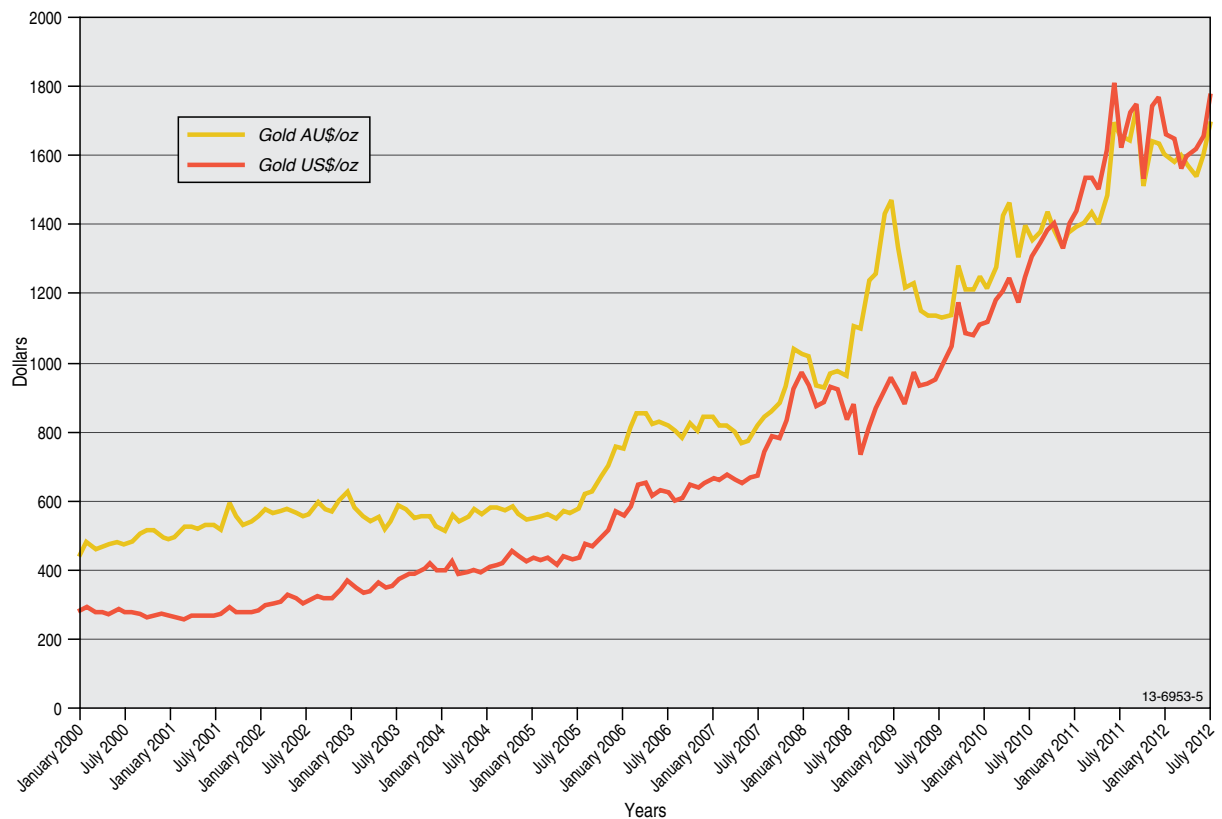


Figure 4. Monthly gold price in US\$ and AU\$ (dollars of the day) since January 2000. (Source: Reserve Bank of Australia figures).

Resources

Australia's gold resources are mined in all States and the Northern Territory (NT) (Fig. 5). At December 2011, total Joint Ore Reserves Committee (JORC) code resources of gold were about 14 288 tonnes, an increase of 388 tonnes from 2010. Allowing for depletion of resources due to production (258 tonnes), new resources added to the national inventory in 2011 totalled 646 tonnes or about 21 million ounces (Moz). Since 2000, nett total JORC Code resources have risen by about 5480 tonnes or 60%, with rises recorded in all States and the NT (Fig. 6). Most of this rise is attributed to South Australia (SA) with a nett increase of 2320 tonnes, largely from the Olympic Dam deposit, while New South Wales (NSW) with 1340 tonnes and Western Australia (WA) with 972 tonnes also contributed significantly. The largest increase in delineated total JORC Code resources, including that lost to production during the same period, was in WA amounting to about 3050 tonnes.

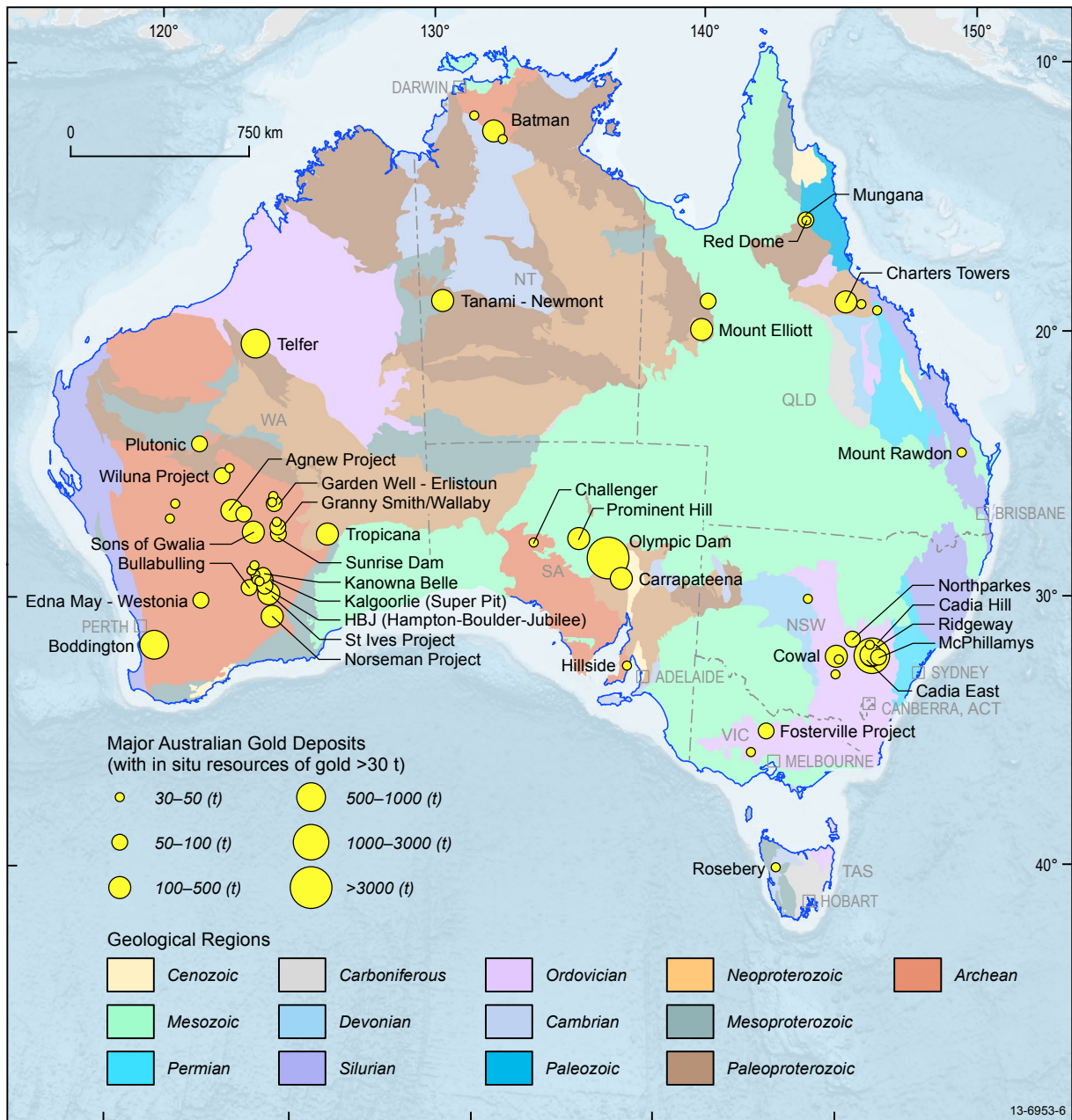


Figure 5. Australian gold deposits with significant resources.

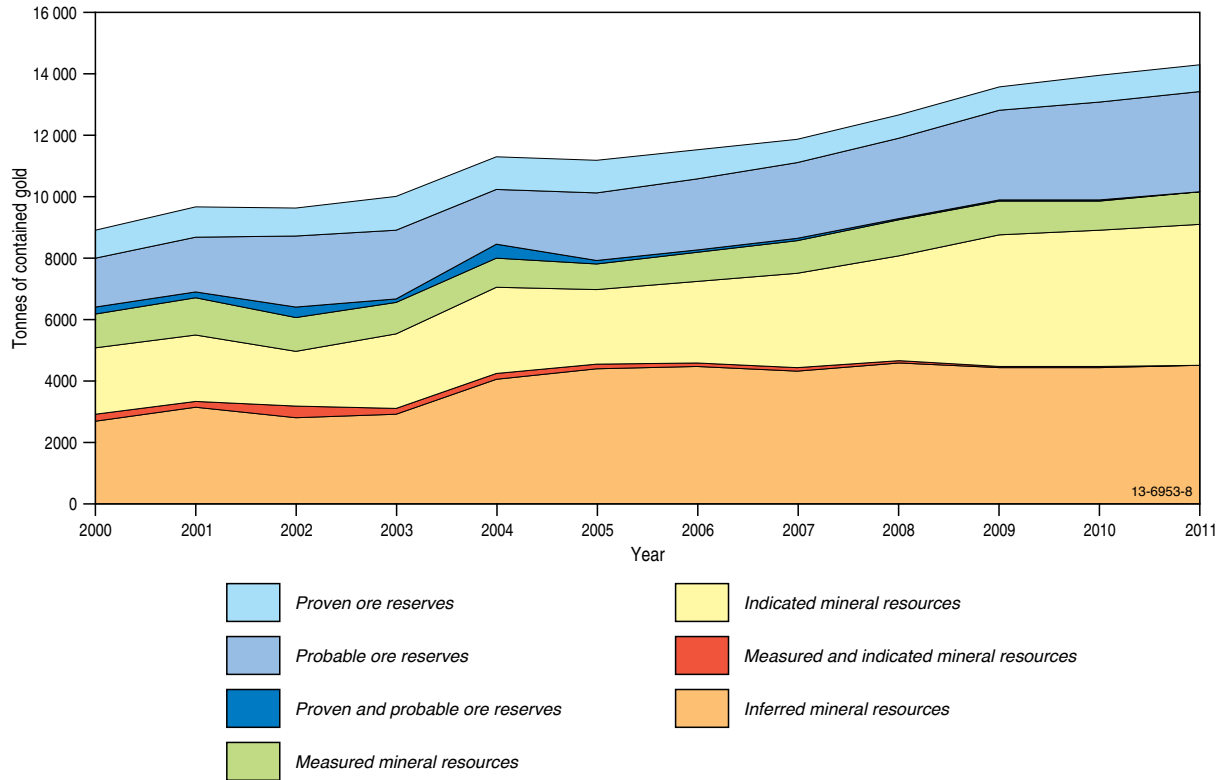


Figure 6. Australian gold within JORC Code categories (from 2000 to 2011).

Australia's Economic Demonstrated Resources (EDR²) of gold are the largest for any country in the world and account for about 17% of the total as estimated by the United States Geological Survey. National EDR increased by 743 tonnes (24 Moz) to 9153 tonnes in 2011 with rises in all States and the NT. However, about 60%, or 443 tonnes, of this rise is attributable to the reclassification of Paramarginal Resources into EDR as a result of persistently higher gold prices and inferred increased economic viability of deposits. Western Australia continued to have the greatest share of EDR with 4058 tonnes, up about 490 tonnes or 1% on 2010 figures. South Australia with 2731 tonnes and NSW with 1645 tonnes contributed the second and third most to the national total. After WA, Queensland (Qld) saw the next largest growth in EDR of 108 tonnes increasing the State total to 482 tonnes for 2011. Between 2000 and 2005, the growth of EDR of gold was relatively flat and varied between about 5000 and 5500 tonnes. Since that time, and coincident with an increase of the gold price from US\$430 to US\$1700/oz, EDR has increased by about 3600 tonnes or nearly 70%. Currently, just under 50% of Australia's EDR of gold is derived from ore reserves as defined under the JORC Code (Fig. 7).

2 EDR is composed of total JORC Resources less Inferred Mineral Resources and those resources from other categories considered to be Paramarginal or Submarginal.

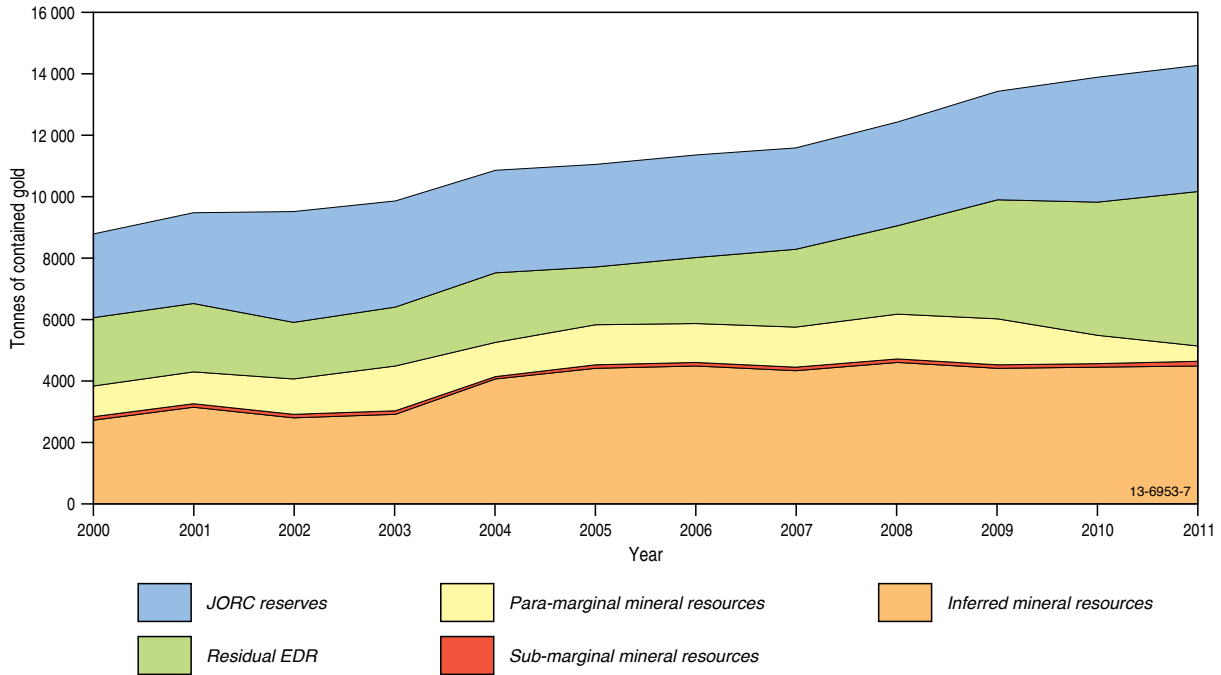


Figure 7. Australian gold resources within categories of National Mineral Resources Scheme (from 2000 to 2011).

Notes: Economic Demonstrated Resources of gold comprising JORC Code reserves (blue) plus Measured and Indicated Mineral Resources deemed to be economic (green). EDR have grown from about 5000 tonnes to about 9000 tonnes since 2000. Paramarginal resources (yellow) have declined in recent years as a result of increasing gold price. Inferred Mineral Resources (orange) have remained relatively constant around 4400 tonnes since 2004 indicating a level of equilibrium between defining new resources and upgrading resources to JORC Code categories with greater certainty.

Around 70% of Australia’s EDR of gold are contained in just 15 deposits. The four largest deposits - Olympic Dam in SA, Cadia East in NSW and Boddington and Telfer in WA - account for more than 50% of gold EDR.

Paramarginal Resources declined by 443 tonnes to 487 tonnes in 2011 or by almost 50%. The sustained substantial rise in the price of gold over the past few years has led to the reclassification of much of this resource category to EDR. Western Australia retained the largest amount of Paramarginal resources at 343 tonnes or about 70% of the national total, ahead of NSW with 49 tonnes.

Submarginal Resources rose by 15 tonnes during 2011 to approximately 135 tonnes. Again, WA had the largest share of this resource category with 96 tonnes while Qld was second with 20 tonnes. Combined Paramarginal and Submarginal resources accounted for 12 to 13% of total JORC Code resources for gold, between 2000 and 2008 however this figure dropped to only 4.3% in 2011 (Fig 7).

National Inferred Mineral Resources of gold rose by just 63 tonnes in 2011 to 4513 tonnes with the largest rises in SA (87 tonnes) and the NT (50 tonnes). Of some concern was the drop of 109 tonnes in WA to 1791 tonnes, or by 6% on its 2010 total. Inferred Mineral Resources are the dominant source material upgraded to JORC Code categories with higher geological certainty. National Inferred Mineral Resources rose from about 2700 tonnes in 2000 to about 4400 tonnes in 2005. Since then, the figures have stabilised in a much narrower range between 4300 and 4600 tonnes, indicating a degree of equilibrium between the definition of new Inferred Mineral Resources and conversion to resource categories with higher geological certainty. Western Australia with 1791 tonnes, or 40% of the total, and SA with 1158 tonnes, or 26% of the total, continued to maintain their dominance of the Inferred Resource category.

Accessible EDR

Australia’s EDR for gold are essentially unencumbered with around 30 tonnes, or less than 1%, currently unavailable for exploitation. Deposits which contain gold resources that are unavailable for mining include Jabiluka, Koongarra, and Coronation Hill, which are all located in the NT.

JORC Reserves

JORC Code reserves comprise total resources in Proven and Probable Ore Reserves as defined in the JORC Code. In 2011, JORC Code reserves of gold amounted to 4131 tonnes, an increase of about 61 tonnes over the 2010 figure. These reserves accounted for 45% of national EDR (Fig. 7) and 29% of total JORC Code resources for 2011. While the majority of operating mines published JORC Code reserves, which were the basis for mining and production, anecdotal evidence suggests that a number of operations were mining from mineral resources of lower economic certainty, such as Castlemaine Goldfields Ltd (now LionGold Corporation) at Ballarat in Victoria (Vic). Periodically, some operations have also undertaken what is essentially trial mining because irregularly distributed, coarse gold has precluded the establishment of meaningful JORC Code compliant resource figures; as was the case in recent years for Ramelius Resources Ltd at the now completed Wattle Dam Mine in WA.

Exploration

Total mineral exploration expenditure, as reported by the Australian Bureau of Statistics³, increased by \$1104 million to \$3574 million in 2011. Expenditure on gold exploration increased for the year by just \$85 million (up 14%) to \$709 million and was overtaken by that spent on iron ore (\$905 million), coal (\$754 million) and combined base metals (\$740 million; lead, zinc, silver, nickel, and cobalt).

Western Australia saw the greatest increase in expenditure on gold of about \$87 million bringing its total for the year to \$499 million or 70% of total gold exploration expenditure. The NT attracted an additional \$26.9 million raising its total for 2011 to \$73.8 million, second only to WA in expenditure on gold. In contrast, gold exploration expenditure dropped 35% to \$34.4 million in Vic and by 17% to \$40.3 million in NSW. Only minor changes in expenditure occurred in Qld, (up \$1.8 million) SA (down \$2.5 million) and Tas (down \$0.8 million).

Reviewing annualised discovery costs per ounce yields highly variable results, partly reflecting differing lag times between company expenditure on exploration and the publication of new or updated resources. Furthermore, there is not a consistent relationship between exploration expenditure and the definition of new resources. Nonetheless, analysing these data over several years can minimise the influence of short term variability factors. Between 1992 and 2011, the annual discovery cost per ounce has varied between about \$10 and \$60/oz with a median cost of \$26/oz. Between 2005 and 2011, the discovery price varied between \$12 and \$38/oz with a median value of \$28/oz, only marginally higher than the longer term statistic. The one cautionary note to keep in mind is that these figures cover all gold deposits, including the large-tonnage copper-gold types, and not just the lode-gold types from which most production is currently sourced.

Expenditure on gold exploration is not differentiated in available statistics between brownfields (existing deposits) and greenfields (new projects). However, exploration expenditure for all mineral commodities on brownfields projects increased by \$892 million to \$2429 million in 2011, representing 68% of the total. At the same time, expenditure on greenfields projects increased only \$191 million to \$1144 million equating to a drop of 6% of its share of total exploration expenditure for all mineral commodities.

Production

The Perth Mint in WA is the sole refiner of gold in Australia, acquiring raw material from domestic mine production, recycled materials and from sources overseas. Total refined gold for 2011 amounted to 319 tonnes, of which about 308 tonnes, worth an estimated \$15.9 billion was exported, a decrease of 22 tonnes on 2010.

While domestic mine production fell marginally by two tonnes to 258 tonnes in 2011, it remained significantly higher than the most recent low point of 215 tonnes in 2008, but still lower than the production highs of about 310 tonnes in the late 1990s. The spread of mine production between the States and the NT remained essentially the same in 2011 as in 2010, with 180 tonnes or almost 70% derived from WA (Table 8). New South Wales with 30 tonnes and Qld with 16 tonnes contributed the second and third most, respectively, to the national gold mine production figures. Gold was a primary output of about 75 operations with many drawing ore from two or more deposits and/or from both open pit and underground sources. Nearly 20 additional operations produced gold as a by-product from processing other commodities such as in polymetallic base-metal deposits at Rosebery, Olympic Dam and Prominent Hill.

³ The figures for exploration expenditure on gold may only be considered an approximation as ABS assigns company provided expenditure on polymetallic deposits (e.g. copper-gold) to the first named commodity.

Table 8. Gold production by State/Territory for the past six years. Western Australia continued to dominate Australian production figures in 2011. Sources: Australian Bureau of Statistics and the Bureau of Resources and Energy Economics.

	2006 tonnes	2007 tonnes	2008 tonnes	2009 tonnes	2010 tonnes	2011 tonnes
Queensland	22	23	18	16	15	16
New South Wales	27	35	31	25	30	30
Victoria	6	6	5	8	7	5
Tasmania	5	4	5	4	4	4
South Australia	7	7	7	8	13	14
Northern Territory	14	17	15	10	10	9
Western Australia	165	156	134	152	181	180
Australia	246	248	215	223	260	258

Gold deposits can be grouped into a number of types with differing contributions to resources and production (Table 9). In 2011, lode-gold deposits of Archean age again accounted for the largest share of production at just over 50% of total mine production, or 134 tonnes, down 24 tonnes from that in 2010. Output from other copper-gold deposits including porphyry types increased by about 20 tonnes to 68 tonnes in 2011, almost off-setting the drop in production from the Archean lode-gold types, while production from the remaining types remained largely the same as 2010. Economic Demonstrated Resources for all the tabulated deposit types increased in 2011 with that of Archean lode-gold types increasing the most at 236 tonnes. However, this increase was partially offset by a drop of 71 tonnes in Inferred Mineral Resources. The EDR of Proterozoic lode-gold deposits saw the second largest gain of 193 tonnes, and, coupled with an additional 106 tonnes of Inferred Mineral Resources, saw the largest increase in total JORC Code resources.

Table 9. Economic Demonstrated Resources (EDR), Inferred Resources and mine production of gold (in tonnes) for 2011 categorised by deposit type. Also shown are category percentages of the respective total resource types, or mine production. Lode gold deposits of Archaean age dominate current mine production, but lower grade copper-gold deposits of various styles comprise the majority of Australia's current resources. Other Cu-Au/Au-Cu deposits include Telfer and Boddington in WA and the porphyry related mineralisation at Northparkes and Cadia in NSW. Surbiton Associates Pty Ltd is gratefully acknowledged for providing the data behind the mine production figures.

Deposit Type	EDR – Tonnes Au (%)	Inferred Resources – Tonnes Au (%)	Mine Production – Tonnes Au (%)
Lode Au Archean	2396 (26.2%)	1539 (34.1%)	134 (51.9%)
Lode Au Proterozoic	623 (6.8%)	406 (9.0%)	18 (7.0%)
Lode Au Phanerozoic	257 (2.7%)	627 (13.9%)	19 (7.4%)
Iron Oxide Cu-Au	2483 (27.1%)	1247 (27.6%)	13 (5.0%)
Other Cu-Au/Au-Cu	3003 (32.8%)	457 (10.1%)	68 (26.4%)
Polymetallic base metals	260 (2.8%)	126 (2.8%)	4 (1.55%)
Other	131 (1.5%)	111 (2.5%)	2 (0.8%)

World ranking

Based on estimates provided by the United States Geological Survey (USGS) and adjusted for Australian figures (Geoscience Australia), world economic resources of gold increased by only 940 tonnes in 2011 to 52 740 tonnes. Australia, with EDR of 9153 tonnes, or 17% of world resources had the largest share, followed by South Africa with 6000 tonnes or 11% and Russia with 5000 tonnes or 9%. Also based on USGS figures, world mine production of gold increased by about 190 tonnes to 2700 tonnes in 2011. Australian gold mine production for the year amounted to 258 tonnes, or about 10% of the world total, and was ranked second behind China with 355 tonnes, but was ahead of the United States of America with 237 tonnes, Russia with 200 tonnes and South Africa with 190 tonnes. Over the past decade, world mine production has fluctuated between a trough of 2264 tonnes in 2008 and the current

estimated peak of 2700 tonnes. Over the same period, consistent increases in China's output from 185 tonnes in 2001 to 355 tonnes in 2011 have been offset by declining production in South Africa from 402 tonnes to 190 tonnes, Canada from 160 tonnes to 110 tonnes and the USA from 335 tonnes to 237 tonnes. Estimated production rates for other countries over the same period are more irregular. Australia's mine production of gold peaked most recently at 310 tonnes in 1998, declining steadily to 215 tonnes in 2008, before recovering to 260 tonnes in 2010, still 50 tonnes below 1998 levels.

Industry Developments

Increased mineral exploration expenditure and sustained, though volatile, increases in the price of gold in 2011 over that in 2010 coincided with considerable activity in the gold industry. As in 2010, further assessment of deposits led to feasibility studies, and mines on care and maintenance brought back into production, while several processing plants and mining operations increased capacity. The industry also saw some mine closures as well operations experiencing lower gold production levels due to reduced ore volumes being processed or falling grades of mill feed.

The following selected announcements provide an overview of industry activities for 2011.

Queensland

Deutsche Rohstoff AG stated that production had commenced from its **Georgetown** operation.

Breakaway Resources Ltd released news that underground mining had recommenced at the **Eloise Copper (gold) Mine**, southeast of Cloncurry.

The **Mount Carlton** Project, south of Townsville, was given the go ahead by Conquest Mining Ltd (now Evolution Mining Ltd).

Ivanhoe Australia Ltd announced positive results from a study of the **Osborne Copper Gold Project**, south of Cloncurry and indicated that production would recommence in March 2012. The company also announced positive results of a scoping study of the **Mount Dore Copper-Gold Project**, also south of Cloncurry.

Xstrata advised of the commencement of underground mining at **Ernest Henry**, north of Cloncurry.

The **Lorena Gold Project**, east of Cloncurry, was purchased by Malachite Resources Ltd which also announced its intention to undertake a mining feasibility study of the project.

New South Wales

Positive feasibility study results were released for the **Hera** deposit, south of Cobar, by YTC Resources Ltd.

Kimberley Metals Ltd (now KBL Mining Ltd) completed refurbishment of the **Mineral Hill** copper-gold plant north of Condobolin and commenced production of concentrate.

Approvals were received by Cortona Resources Ltd for the development of the **Dargues Reef Mine**, south of Braidwood.

Victoria

AuRico Gold Inc. acquired the **Fosterville Gold Mine**, east of Bendigo, and Stawell **Gold Mine** through a takeover of Northgate Minerals Corporation and subsequently sold the operations to Crocodile Gold Corp.

Octagonal Resources announced the first gold pour from the recommissioned plant at **Porcupine Flat**, Maldon.

Morning star Gold NL announced that mining had recommenced at the **Morning Star Gold Mine**, Woods Point.

Mine production recommenced at **Ballarat** and Castlemaine Goldfields Ltd announced its first gold pour from the project.

Unity Mining Ltd closed its **Kangaroo Flat Mine** at Bendigo.

Tasmania

BCD Resources NL announced that the **Tasmania Mine** at Beaconsfield would close in 2012.

The **Hellyer** plant refurbishment was completed by Bass Metals Ltd and brought into production.

Frontier Resources Ltd intersected 17.6 metres at 10.8 grams per tonne of gold at the **Stormont** deposit in the Moina region, south of Burnie.

Northern Territory

Crocodile Gold Corp announced extraction of the first ore from the **Cosmo** underground development, northwest of Pine Creek. The company also announced positive results from a mine development study of the **Maud Creek** deposit, east of Katherine.

The feasibility study on the **Mount Todd Gold Project** by Vista Gold Corp continued.

Tanami Gold NL announced a mineral resource containing 535 000 oz of gold for the **Groundrush** deposit, northeast of Tanami.

A maiden resource containing 1.6 Moz of gold for the **Buccaneer Porphyry**, south of Tanami, was released by ABM Resources NL.

South Australia

Oz Minerals acquired the **Carapateena** copper-gold deposit, north of Port Augusta.

Rex Minerals Ltd released scoping study results for the **Hillside** iron-copper-gold deposit near Ardrossan, Yorke Peninsula.

Hillgrove Resources Ltd commenced production at **Kanmantoo** copper-gold-silver mine east of Adelaide.

Western Australia

Alacer Gold Corp announced a commitment to replacing the 1.2 Million tonnes per annum (Mtpa) **Jubilee** plant with a new 2.5 Mtpa plant to treat the increased resources at its **South Kalgoorlie Operations**.

Barra Resources Ltd announced the signing of a tribute agreement enabling the recommencement of production from the **Burbanks Gold Project**, Coolgardie.

Gold Road Resources Ltd reported a maiden resource containing 150 000 oz of gold for the **Central Bore** deposit located about 150 kilometres northeast of Laverton.

Integra Mining Ltd announced commissioning of the **Salt Creek Mill**, southeast of Kalgoorlie, was completed, and subsequently upgraded the plant by 25% to 1 Mtpa capacity.

KCGM commenced the Golden Pike cutback of the **Fimiston Open Pit** (Super Pit) at Kalgoorlie.

Millennium Minerals Ltd secured finance to underpin construction of the **Nullagine** gold project.

Nex Metals Explorations Ltd received approvals to recommence mining of the **Butterfly Pit** south of Leonora.

Phoenix gold released the results of a feasibility study of the **Catherwood** deposit north of Coolgardie and poured its first gold from stockpile treatment.

Ramelius Resources Ltd announced that mining would proceed at its **Mount Magnet Project**.

Range River Gold Ltd placed its **Mount Morgans** operation, west of Laverton, on care and maintenance as administrators were appointed.

Results of a positive feasibility study of the **Garden Well** deposit, north of Laverton, were released by Regis Resources Ltd.

St Barbara Ltd announced that production commenced at the **King of the Hills** underground mine north of Leonora.

Silver Lake Resources reported that the expansion of the **Lakewood Processing Facility** at Kalgoorlie to 700 000 tonnes per annum (tpa) was completed while the stage two upgrade to 1 Mtpa was in progress. The company also advised that ore production commenced from its **Wombola** open pit near Mount Monger, southeast of Kalgoorlie.

Tanami Gold NL completed a plant upgrade at **Coyote** to 350 000 tpa.

Iron Ore

Daisy Summerfield (daisy.summerfield@ga.gov.au)

Iron (Fe) is a metallic element which constitutes about 5% of the Earth's crust and is the fourth most abundant element in the crust. Iron ores are rocks from which metallic iron can be economically extracted. The principal iron ores are hematite (Fe_2O_3) and magnetite (Fe_3O_4).

Hematite is an iron oxide mineral. It is non-magnetic and has colour variations ranging from steel silver to reddish brown. Pure hematite mineral contains 69.9% iron. It has been the dominant iron ore mined in Australia since the early 1960s and approximately 96% of Australia's iron ore exports are high grade hematite, most of which has been mined from deposits in the Hamersley province in Western Australia (WA). The Brockman Iron Formation in the Hamersley province is a significant example of high grade hematite iron ore deposits.

Magnetite is an iron oxide mineral generally black in colour and highly magnetic, the latter property aiding in the beneficiation of magnetite ores. Magnetite mineral contains 72.4% iron, which is higher than hematite but the presence of impurities results in lower ore grade, making it more costly to produce the concentrates used in steel smelters. Magnetite mining is an emerging industry in Australia with large deposits in the Pilbara region of WA being developed.

The largest project, which has a current value of more than \$6 billion, is the Sino Iron project being developed by the Chinese company CITIC Pacific. Other major magnetite projects include the \$2.6 billion Karara joint venture project, which is owned by Gindalbie Metals and Chinese steel producer, Ansteel, and the \$2.8 billion Southdown magnetite project owned by Grange Resources. Sino Iron project is gearing up for commencement of production while the Karara Magnetite Iron Ore Project commenced production of magnetite concentrate in December 2012. Grange Resources' Southdown Magnetite development at Albany WA was planned to start in 2015 but that may change due to the current economic environment.

Mining and processing hematite and magnetite ores

High grade hematite ore is referred to as direct shipping ore (DSO) because it is mined and the ores go through a relatively simple crushing and screening process before being exported for use in steel making. Australia's hematite DSO from the Hamersley region in WA averages from 56% to 62% iron. Like hematite ores, magnetite ores require initial crushing and screening, but undergo a second stage of processing that relies on the magnetic properties of the ore and involves magnetic separators to extract the magnetite and produce a concentrate.

Further processing involves the agglomeration⁴ and thermal treatment of the concentrate to produce pellets which can be used directly in blast furnaces, or in direct reduction steel making plants. The pellets contain 65% to 70% iron, which is a higher iron grade than hematite DSO currently being exported from the Hamersley region. Additionally, when compared to hematite DSO, the magnetite pellets contain lower levels of impurities, particularly phosphorous, sulphur and aluminium. These pellets are premium products which attract higher prices from steel makers, offsetting the higher costs of producing magnetite pellets.

Worldwide production trends

Hematite ores dominate the world production of iron ores and are sourced mainly in Australia and Brazil. Magnetite is increasing its presence in world production and this trend is likely to increase when large magnetite projects such as the Karara Iron, Southdown magnetite and Sino Iron projects are operational.

During 2011, China was the world's largest producer of iron ore with 43%, or 1200 million tonnes (Mt) followed by Australia with 17% or 488 Mt and Brazil with around 14% or 390 Mt of world production.

⁴ Agglomeration is the process in which magnetite grains are aggregated into pellets using a chemical binding reagent. Pellets are produced in a pelletising plant.

Resources

Map showing locations of Australia hematite and magnetite deposits and total resources are at :

- https://www.ga.gov.au/image_cache/GA21217.pdf
- https://www.ga.gov.au/image_cache/GA21218.pdf

In previous years, Geoscience Australia reported estimates of Australia's national resources of iron as tonnes of iron ore because these resources were dominantly hematite ores. However, as a result of on-going exploration and assessment of magnetite deposits, Australia has now identified substantial reserves and resources in both hematite and magnetite ores. Because of the high average grades (% Fe) of hematite ores when compared to the average grades for magnetite ores, it is necessary to report national resources in terms of contained iron. Accordingly, Australia's national resources of iron are now reported in two categories:

- Tonnes of iron ore, and
- Tonnes of contained iron.

Iron ore: In 2011, Economic Demonstrated Resources (EDR) of iron ore increased by 9% to 37 762 Mt, mainly as a result of resource increase for some deposits, including in the WA mines, BHP Yandi, Mining Area C, Nullagine, Hamersley and Hope Downs. Resource definition of existing deposits and the inclusion of new magnetite deposits have also contributed to the increase in EDR. Paramarginal Demonstrated Resources have increased from 700 Mt to 1414 Mt. The Inferred Resource increased by 29% to 61 489 Mt, mainly because of increases in some deposits in the Hamersley and Mining Area C mine operations. The inclusion of new and newly defined resources for existing deposits also contributed to the increased Inferred Resources for 2011. Western Australia has about 94% of Australia's total Identified Resources of iron ore with the majority of the resources occurring in the Pilbara Region.

However, South Australia (SA) is emerging as the second largest producer of iron ore in Australia, accounting for more than 5% of the total EDR. Australia's EDR has a resource life of 77 years. Figure 8 and Figure 9 show iron ore EDR and Inferred resources for each State and for the Northern Territory.

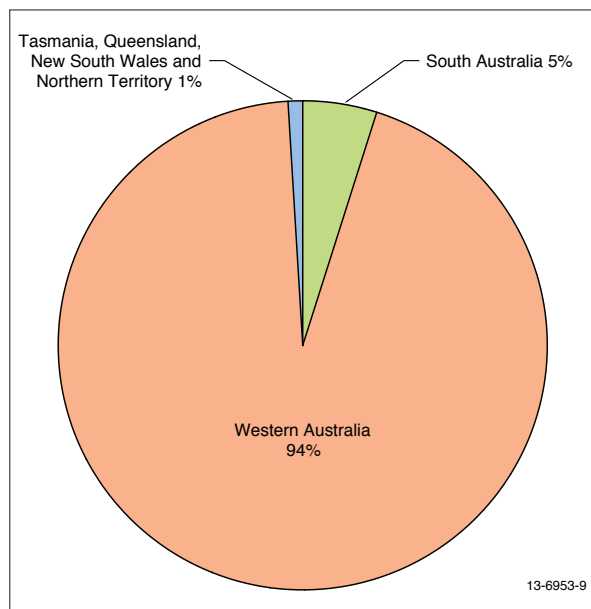


Figure 8. Proportion of iron ore EDR in States and NT.

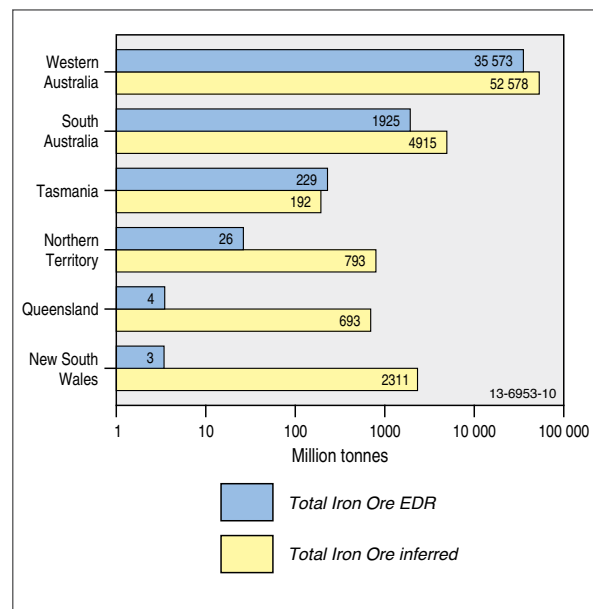


Figure 9. Total EDR and Inferred resources of iron ore in States and NT.

Contained Iron: As at December 2011, Australia's EDR of contained iron was estimated to be 18 152 Mt while Paramarginal Resources were 501 Mt and Inferred Resources were 29 204 Mt.

Accessible EDR

Australia has Accessible EDR (AEDR) of iron ore totalling 37 762 Mt, of which 94% occurs in WA.

JORC Reserves

The total Joint Ore Reserve Committee (JORC) Code Reserves of iron ore were estimated to be 15 032 Mt, representing 40% of accessible EDR. Contained iron is 7804 Mt, or 43% of the EDR. However, unreported reserves and resources are not included, resulting in a loss of accountability. Based on the data which is publicly available, JORC Code Reserves are sufficient for approximately 31 years at the current rate of mine production.

Several companies have reported initial resources on either new or known deposits that are now being drilled for resource development which have contributed to Australia's iron ore resource base for 2011. These deposits include the Nyidinghu (Fortescue Metals Group Ltd), McCamey's North (Atlas Iron Ltd), Weckl and Buckland Hills (Aquila Resources Ltd), Byro FE1 (Athena Resources Ltd), Mount Alexander (Zenith Minerals Ltd), Cohen (Buxton Resources Pty Ltd), Mount Philp (Cerro Resources NL), Muster Dam (Minotaur Exploration Ltd), Peak Hill (Padbury Mining Ltd JV), Area C, Robinson Range Iron Project (PepinNini Minerals Ltd), Feral, Perenjori Iron Ore project (Quest Minerals Ltd) and Die Hardy (Radar Iron Ltd). These deposits are a few of the new deposits that were reported and some are discussed in 'Industry Developments' section of this report.

Exploration expenditure

Australian Bureau of Statistics (ABS) data indicates that iron ore exploration expenditure in Australia for 2011 totalled \$905.3 million, a 64% increase on the \$553.1 million spent in 2010. About \$802.4 million was spent on iron ore exploration in WA which represented 89% of total iron ore exploration expenditure. Western Australia also accounted for 25% of the total mineral exploration expenditure in Australia during 2011, which amounted to around \$3573.3 million. Iron ore exploration expenditure in SA was \$63.5 million, Northern Territory (NT) \$30.0 million and Tasmania (Tas) was \$1.5 million.

Production

Australia's total production of iron ore for 2011 was 488 Mt with WA producing 474 Mt, or 97% of overall production. South Australia increased its iron ore production from approximately 9.2 Mt in 2010 to just over 10 Mt for 2011, which represented 2% of Australia's total production of iron ore. South Australia's iron ore resource is small when compared with Western Australia, but it is emerging to become the second major iron ore producing State.

The Bureau of Resources and Energy Economics (BREE) reported Australia's iron ore exports during 2011 to be 439 Mt, a 9% increase from 2010 of approximately 402 Mt. BREE has forecast an increase in iron ore exports of at least 12% or 493 Mt in 2012 and around 6% or 525 Mt in 2013. Project expansions by large operations such as Rio Tinto and BHP to medium operations by the Fortescue Metals Group will support these projected increases. The anticipated large magnetite project production by Sino Iron also is included in the predicted increases. The predictions are a direct response to increasing consumption from developing countries such as China, India and Brazil. BREE forecast an increase in steel consumption between 2013-17 by China (4% per year), India (7% per year) and Brazil (3%) as a result of major infrastructure, rail, highways, and public housing developments. The iron ore industry has echoed the sentiment of an increase in global demand, but is expecting a slower rate of growth.

World ranking

Australia has the world's largest EDR with 22% of the world's iron ore followed by Brazil with 17%, Russia with 15% and China with 14%. In terms of contained iron, Australia has 22% of world EDR while Brazil has the second largest EDR with 20%.

Industry Developments

Western Australia

Rio Tinto Ltd: Rio Tinto US\$15 billion investment for its five years growth program which started in 2010 has been the centre of events during the 2011. The company's growth expansion for its Pilbara operations will include, but is not limited to, the Brockman 4 mine increasing capacity from 22 Mt to 40 Mt per annum (Mtpa), extending mine life at Marandoo Mine to 16 years and increasing to 15 Mtpa capacity of the new open cut mine at Hope Downs 4. These expansion projects are aimed at increasing Rio Tinto's production to 353 Mtpa by 2015. The first stage for 225 Mtpa production capacity was achieved during the first quarter of 2011.

An additional highlight for Rio Tinto was the approval by the Western Australian Government of the company's infrastructure project planned for the town of Wickham. This project will give more support to the company's growth program by providing accommodation for the project's workforce. The government states that this infrastructure development will compliment the State's Pilbara cities initiative. Rio Tinto says that the planned infrastructure and company expansion will enable it to meet the anticipated increase in demand from the Chinese steel industries, initially from its current production of 700 Mtpa and later through growth to around one billion tonnes per annum towards 2030.

BHP Billiton Ltd: The company's Western Australia Iron Ore (WAIO) reported a record production for the year ended December 2011, raising its annual capacity to 178 Mtpa. One of the highlights for 2011 was the company's approval for the development of the new Orebody 24 mine in the Pilbara region of WA which is reported to be worth US\$822 million. The development will include infrastructure such as an ore crushing plant, train loadout facility, rail spur and other supporting facilities. The new mine has a projected capacity of 17 Mtpa and will help to maintain the company's Mount Newman joint venture operations production output contributing to BHP's near term production target of 350 Mtpa. Completion of the Rapid Growth Project 5 (RGP5) expansion projects will also contribute to the anticipated increase production capacity to 220 Mtpa. BHP reported that the initial production from RGP5 occurred during the third quarter of 2011.

Infrastructure development projects which will service the WAIO operations are in progress but large capital projects such as the outer harbour project have been delayed in favour of developing the inner harbour expansion project. This change follows an evaluation by BHP which demonstrated the cost benefit of expanding the existing inner harbour. The expansion will include the development of two additional berths which, according to the company, will increase the inner harbour capacity to 220 Mtpa. It is anticipated that the commissioning of the inner harbour will be in the second half of 2012.

Fortescue Metals Group (FMG): In October 2012, FMG announced the commissioning of its 25 Mtpa second Ore Processing Facility (OPF) at Christmas Creek 110 km north of Newman in the Pilbara region. The company reports that the second OPF will lift the capacity of Christmas Creek mine to 50 Mtpa which will result in combined output of Christmas Creek and nearby Cloudbreak to 95 Mt by end of 2012. This development marks another milestone in the company's expansion plan to increase production capacity to 115 Mtpa by end of the first quarter in 2013 through the addition of the anticipated first ore production from the Solomon Firetail mine. The company has also announced initial reserves for the Solomon Hub of approximately 716 Mt. These reserves are a compilation of several deposits, including 200.9 Mt at the Firetail mine.

CITIC Pacific Ltd: When commissioned, the company's Sino Iron project will be Australia's largest magnetite iron ore development project. The project will have six production lines with the capacity to produce a total 24 Mtpa of magnetite concentrate. The company reports that some of the project supporting infrastructure has been completed, including a 30 km slurry pipeline, while integration of a power station, desalination plant and the port area are ready for commissioning. The first of the six production lines is in its final phase and work on the second production line has started.

Atlas Iron Ltd: The company has announced development and expansion plans for its Horizon 1 Growth Program categorised into three phases. The initial phase will include expansion of the pit for its existing Wodgina operation and the development of a new Mount Dove mine approximately 70 km south of Port Hedland and the Abydos mine 130 km south of Port Hedland. The company anticipates production growth of 10 Mtpa by 2013 once Mount Dove and Abydos are operational. Phase 2 of the Horizon 1 development will bring the company's production capacity to 12 Mtpa through its joint venture (with Altura Mining Ltd) Mount Webber mine project.

Gindalbie Metals Ltd: The first production of magnetite concentrate by Karara Iron Ore Project was announced in November 2012. The Karara Iron Ore Project is being developed by Karara Mining Limited, which is a 50:50 Joint Venture between Gindalbie Metals and Chinese steel producer, AnSteel. The company is currently ramping up production towards a target rate of 8 Mtpa. Gindalbie also reported a 1.5 billion tonne initial resource for the Lodestone magnetite project in 45 km southeast of the Karara project in WA's mid-west region. The company reports that, based on initial analysis, the Lodestone project has the potential to produce a magnetite concentrate grading at more than 63% iron with low impurities. The company also says that the Lodestone project can potentially become one of its stand-alone mine operations in the future.

Brockman Resources Ltd: Environmental approval for the development of the company's Marillana Iron Ore Project was received from the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) and from the Western Australian Environmental Protection Authority. To date, the company has focused on securing rail and port infrastructure for the project and has formed an alliance agreement with QR National Ltd and Atlas Iron Ltd to conduct pre-feasibility and definitive feasibility studies for integrated mine, rail and port logistics for the East Pilbara region. Subject to the pre-feasibility study results, the alliance aims to complete the definitive feasibility study by 2013 with relevant infrastructure completed by 2016. The Marillana Iron Ore Project is located approximately 100 km northwest of Newman in the Pilbara region.

Cashmere Iron Ltd: The company has announced that it has entered an agreement with Esperance Ports Sea and Land for access to the expanded port at Esperance in the Great Southern region. The agreement allows for an allocation of 5 Mt once the port expansion occurs and a commercial agreement is reached between Cashmere Iron and the port operator. The company says that the agreement is important for the development of its Cashmere Down iron ore project. In its Annual Report, Cashmere Iron stated that three potential types of materials (hematite DSO, detrital iron deposit and magnetite) have been identified at Cashmere project which can be produced to marketable iron ore products. The company has reported Cashmere Down JORC Code compliant Resources of 1059 Mt (Measured 202 Mt, Indicated 779 Mt and Inferred 78 Mt).

Australasian Resources Ltd: The company has increased its rights to mine approximately one billion tonnes of iron ore at its flagship Balmoral South Iron Ore Project about 80 km southwest of Karratha. This was through a memorandum of understanding with its main share holder, Mineralogy Resources Ltd. In return, Mineralogy Resources earned a 50% interest in the Australasian Resources wholly owned subsidiary, International Minerals Pty Ltd. Another highlight for Australasian Resources has been the completion of the Balmoral South feasibility study update carried out by Promet Engineers, a lead consultant in the original feasibility study in 2008.

Flinders Mines Ltd: The Mining Lease for two tenements (Blacksmith and Anvil) at the company's Pilbara Iron Ore Project was granted during the year. The project is located about 60 km northwest of Tom Price in the Pilbara region. The company reports that the project's ongoing definitive feasibility study will continue to focus on mine planning, metallurgical testing and marketing. The project will produce up to 15 Mtpa of iron ore with the company reporting a current iron ore resource of 917 Mt at 55.2% Fe.

Venus Metals Corporation Ltd: The pre-feasibility study of the company's joint venture Yalgoo Iron Ore Project has indicated a technically viable and financially robust project. Located in the Yilgarn region of WA, the project has a JORC Code compliant magnetite resource of 698.1 Mt made up of 311.2 Mt Indicated Resource and 386.9 Mt Inferred Resource. Venus Metals reports that the pre-feasibility study was based on annual production of 7.5 Mtpa of magnetite concentrate grading 68% Fe for a mine life of more than 15 years.

Mindax Ltd: In April 2012, the company announced that a scoping study had been completed for the Mount Forrest Iron Project which is in the Yilgarn region about 650 km from the port of Esperance. The study considered two options for product types, beneficiated magnetite and beneficiated hematite direct shipping ore. Mindax stated that the study indicated a potentially robust project for Mount Forrest. The magnetite option was based on a 10 Mtpa production of magnetite concentrate for a mine life of approximate 18 years. Relative to this option, the company has reported a JORC Code Indicated Resource of magnetite totalling 248.2 Mt at 32.6% Fe and a JORC Code Inferred Resource of 14 624 Mt at 31.6% Fe.

Iron Ore Holdings Ltd (IOH): A pre-feasibility study for the company's Bungaroo South Project in the Pilbara region has confirmed the technical and financial viability for a 4 Mtpa to 8 Mtpa operational capacity. The signing of the Native Title agreement and approval of the mining lease for the Bungaroo South and Dragon deposits also added to the

company's highlights during the year. The company says that the completed pre-feasibility study has confirmed that the new Bungaroo South mine will have an operational potential of 4 Mtpa to 8 Mtpa. In November 2012, the company has reported a total of 282.5 Mt of JORC Code Indicated (179.7 Mt at 58% Fe) and Inferred (68.6 Mt at 55.1% Fe) Resources for the Bungaroo South deposit.

Pluton Resources Ltd: Mining lease approval has been granted to the company's Irvine Island project which is located about 130 km north of Derby on the Kimberley Coast of WA. The company states that acquisition of the mining lease is a step forward in achieving the project's commercial development. Pluton Resources has announced an initial ore reserves for the Irvine Island project of 143 Mt at 28% Fe. The company now aims to complete the acquisition of data required to gain government approval for the Irvine Island development.

FairStar Resources Ltd: The company has entered into a Native Title agreement with the Central East Goldfields Peoples Native Title Claimant Group and has been granted a mining lease for on-going exploration and production at the its Steeple Hill Iron Project in WA's eastern goldfields. FairStar state that this is a significant milestone for the company's commitment to bring the Steeple Hill project to the production stage. In June 2011, the company has reported new Indicated Resources for Steeple Hill of approximately 136 Mt of hematite at 58% Fe grade.

Golden West Resources Ltd (GWR): Mining approval was received for the company's John William deposit, which is part of its Wiluna West Project. The approval allows the company to mine up to 1 Mtpa for a three year period. GWR has reported a global resource for the Wiluna West Project of 130.3 Mt at an average grade of 60% Fe. Part of this resource is 10.8 Mt at 64.1% Fe for the John William DSO hematite deposit. Effort to secure port access is a priority for the company.

BC Iron Ltd: A significant milestone for the company's Nullagine joint venture with Fortescue Metals was achieved in December 2011 when more than 1 Mt of iron ore was exported to exceed the company's export target. Another target milestone was a production rate of 3 Mtpa which was increased to 5 Mtpa in May 2012, well ahead of the end of June 2012 target. In addition, the joint venture exported approximately 224 000 wet tonnes of iron ore from Port Hedland's Herb Elliott Port, which was its largest ever shipment.

Cazaly Resources Ltd: The company's Parker Range Iron Ore project about 400 km east of Perth has received environmental approvals, clearing the way for its development. The company also has signed an agreement with the Esperance Port Authority for a 5 Mtpa port allocation. However, this agreement is subject to the completion of the port expansion and acceptance by the port operator, Esperance Ports Sea and Land.

Jupiter Mines Ltd: The company reported that JORC Code compliant resources at its Mount Ida Magnetite Project in the central Yilgarn region had increased by 132% to 1.23 billion tonnes at 29.79% Fe. However, 86% of these are Indicated Resources. The resource estimate is based solely on the Central Zone of the Mount Ida deposit and is likely to increase when recent drilling results on the Northern and Southern extensions are modelled.

Quest Minerals Ltd: The company has reported Inferred magnetite resource of 147 Mt at 36.8% Fe for its Feral prospect at the Perenjori Iron Ore Project in the Yilgarn region. An initial scoping study initiated by the company for the Feral prospect indicated a potentially economic 5 Mtpa operation but the company plans more metallurgical testing to confirm a saleable product for the Perenjori project. The company's 2012 Annual Report states that the proposed metallurgical testings and resource drilling will bring the project into a pre-feasibility study stage.

Aquila Resources Ltd: Recent announcements by the company have outlined further planned developments for its West Pilbara Iron Ore Project with a revised total expenditure for the project estimated to be around \$7.4 billion. The project development will include an integrated new mine, infrastructure and rail. Stage 1 of the project will involve development of eight mining areas and rail infrastructure as well as feasibility studies for both the Mount Stuart Iron Ore Project and the Red Hill Iron Ore Project, which has already delivered an economically viable project. It is anticipated that the total production for Mount Stuart will be 70 Mtpa of iron ore for mine life of 14 years while it is envisaged that the Red Hill project is expected to produce 289 Mt for a mine life of more than 16 years. Aquila stated that mining lease applications for the Stage 1 mining areas have been lodged with the Western Australian Department of Mines and Petroleum.

Legacy Iron Ore Ltd: The company's Mount Bevan Iron Ore Project in the Yilgarn region initially reported mineral resource of 617 Mt but this has been upgraded to 1.6 billion tonnes at 30.2% Fe for the project's western BIF magnetite target. The company anticipates a large proportion of this Inferred Resources will be upgraded to Indicated Resources after relevant tests, such as geochemical testing, of the phase 3 drilling program samples have been completed.

Dynasty Metals Australia Ltd: During 2011-12, the company completed a scoping study of its Spearhole deposit in the Pilbara region, which confirmed the economic potential of the deposit. The Spearhole deposit occurs within the Prairie Downs Iron Ore Project, located approximately 40 km southwest of Mount Newman. The company reported that, in October 2010, the Spearhole deposit has a JORC Code Inferred Resource of 1.4 billion tonnes of Detrital Channel Iron, adding to the previously announced 23.3 Mt of the Marra Mamba Iron Formation in March 2010. Dynasty Metals is currently focused on seeking solutions for the Prairie Downs Project's infrastructure and on holding discussions with relevant stakeholders in the region.

Winmar Resources Ltd: The company has announced a significant increase in resources at its Hamersley Iron project about 50 km north-northeast of Tom Price in the Pilbara region. The Inferred Resources for the project have increased from 241.6 Mt at 54.3% Fe to 368 Mt at 54.7% Fe, which will be used to update of the project's scoping study.

Iron Mountain Mining Ltd: The company has reported that its joint venture with Red River Resources Ltd, the Miaree Magnetite project, has an initial JORC Code Inferred Resource of 286 Mt at an average grade of 31.36% Fe. The project is located approximately 30 km from Karratha and 70 km from the planned Anketell port.

Dragon Energy Ltd: The company has reported the completion of a major mineral resource drill out for its Rocklea and Nameless deposits, resulting in an upgrade of resources for both deposits, which occur within the company's Pilbara Iron Project. The Rocklea resource has been upgraded to 93.59 Mt at 52.19% Fe with over 84% categorised as Indicated Resources. This brings the overall Rocklea deposits resources, which includes the newly acquired Rocklea and Dragon's Rocklea, to approximately 182.6 Mt. An initial resource of approximately 81 Mt at 52.39% Fe also was reported for the Nameless deposit, bringing the overall mineral resource for the company's Pilbara Iron Project to 263.6 Mt.

Mount Gibson Iron Ltd: The first shipment of hematite ore from the company's Extension Hill Project about 260 kilometres east-southeast of Geraldton occurred during the year. The first shipment of ore from the mine, 61 438 tonnes of ore is being shipped to China. The company also says that the Extension Hill Project is moving to an annual production and export rate of 3 Mtpa. In its 2012 Annual Report, the company states that ore reserves for Extension Hill are 12.2 Mt and mineral resource are 19.4 Mt.

Athena Resources Ltd: The company has announced some encouraging assay results from the second phase of its first pass drilling program which was completed in late 2011 at the Byro Iron Ore Project. The assay results were taken from drilling conducted at Byro South, Whitmarsh Find and Whistle Jack magnetite deposits, confirming the magnetic susceptibility reported in late 2011. The company says that the results demonstrate continuity of the high grade mineralisation at these prospects. The company has also reported an initial JORC Code Inferred Resource of approximately 22.8 Mt at 25.6% Fe for its Fe1 prospect, which occurs within the Byro Iron Ore Project, 250 km from Geraldton.

PepiNini Minerals Ltd: The company has reported the results of its drilling program for the Robinson Range Joint Venture project. The program's primary target was to find supergene enriched hematite and hematite-goethite mineralisation associated with banded iron and granular iron formation units of the Robinson Range Formation. Significant intersections, included 24 m at 64.2% Fe from surface and 15 m at 60.7% Fe from a depth of 56 m. Another borehole intersected a 57 m at 56% Fe from 3m including an interval of 33 m from 25 m at 61.8% Fe. The overall outcome of the drilling program has resulted in a JORC Code Inferred Resource of 17.7 Mt at 49.7% Fe for the Area C prospect with a 45% Fe cut-off grade.

Radar Iron Ltd: The company has announced an initial JORC Code Inferred Resource of 2.1 Mt at 57.6% Fe at a cut-off of 55% for its Muldoon prospect at the Johnston Range Iron Ore Project in the Yilgarn region. Radar Iron considers the Johnson range area has significant potential to host numerous hematite enriched deposits and aims to conduct progressive tests in these zones during 2012, with an objective of delineating additional resources. The company claims that the mineralisation at Muldoon deposit is at, or near the surface and making shallow open pit extraction through possible, resulting in a relatively low cost mining and crushing operation.

South Australia

Royal Resources Ltd: The company announced a significant increase in resources for its Red Dragon Venture project as a result of resource definition drilling, mainly from the deposits within the Razorback Premium Iron Project. This included the initial resource for the Iron Peak deposit, bringing the total resources for the Premium Iron Project to approximately two billion tonnes. The company also announced a mining lease proposal to study the Iron Peak, Ironback Ridge and Interzone deposits in the Premium Iron Project, which is part of the Red Dragon Venture.

Iron Road Ltd: The company commenced a definitive feasibility study of its Central Eyre Iron Project. The company also carried out a resource upgrade of the project which increased resources to 2.1 billion tonnes as the result of an ongoing mineral resource expansion program at the Murphy South deposit. The increase includes an upgrade to Indicated Resource of 1.11 billion tonnes.

Minotaur Exploration Ltd: The Company's Muster Dam deposit, which occurs within the Mutooroo Magnetite Project, 100 km southwest of Broken Hill has reported its initial Inferred Resource of 1.5 billion tonnes at a DTR⁵ grade of 15.2% Fe₃O₄. Muster Dam is one of numerous prospects within the Mutooroo Magnetite joint venture project with Sumitomo Metal Mining Oceania Pty Ltd and Minotaur.

WPG Resources Ltd: reported resources at the Giffen Well iron ore deposit in the Gawler Craton estimated to be 688.8 Mt at an average grade of 30.9% Fe with a cut-off grade of 15%. More than 62% of the resource tonnage is in the Indicated category, which has a resource estimate of 427.6 Mt at 31.17% Fe. The Inferred Resource component stands at 261.2 Mt at 30.46% Fe. The company has begun a pre-feasibility study of the project.

Arrium Ltd: The company's new Peculiar Knob mine 90 km southeast of Coober Pedy and 600 kms from Whyalla was commissioned and the first iron ore sale was sent by rail to the port of Darwin in October 2012. Arrium says that the Peculiar Knob mine, which is part of the company's Southern Iron operation, will contribute to its plan to increase iron ore exports to around 12 Mtpa by July/August 2013. As part of this expansion, the company is undertaking a \$200 million project at its Whyalla port export facility to increase handling capacity from approximately 6 Mtpa to 12 Mtpa.

IMX Resources Ltd: reported a positive result for the company's Snaefell project development concept Study. Proceeding to a pre-feasibility study, additional studies for water, power and other project logistics are needed and are in progress. The company expects the remaining studies to be completed in the near future. The Snaefell project is 12 km from the company's Cairn Hill mine and has a current JORC Code Inferred Resource of 569 Mt at 27.1% Fe at a cut-off of 18% Fe.

Centrex Metals Ltd: The company completed a scoping study for its Fusion Magnetite Iron Project and associated nearby Port Spencer proposal on the Eyre Peninsula 35 km north of Port Lincoln and has proceeded to a definitive feasibility study. Both studies assumed production of between 5 Mtpa and 10 Mtpa and exporting through Port Spencer, which is expected to be operational in 2014. The project capital cost to develop the Fusion project and the associated port facilities is estimated to be between \$1.7 billion and \$2.6 billion. Centrex announced the first Indicated mineral resource for Fusion's Koppio deposit of 54.5 Mt, which is part of an overall upgrade to Fusion Magnetite Project Mineral Resource estimate to 499.4 Mt.

Havilah Resources NL: Metallurgical tests based on a range of industry standard measurement criteria for the company's Maldorky Iron Ore Project have indicated a soft ore, which requires lower power during ore processing, including crushing and grinding. Havilah Resources has reported an Indicated Resource of 147 Mt at 30.1% Fe for the Maldorky project, which is approximately 300 km east of Port Pirie.

Lincoln Minerals Ltd: The company is planning a two stage development for a new iron ore mine at its Gums Flat Iron Ore Project on the southern Eyre Peninsula. Stage 1 includes mining the Burns deposit hematite DSO for export of 0.5 Mtpa for a mine life of three to five years. The DSO includes an upgrade of around 1 Mtpa lower grade hematite-goethite-magnetite to DSO. The company's Annual Report states that the Gum Flat project draft mining lease application was completed, and project planning and background studies, including a community consultation process, is ongoing. Stage 2 consists of mining the magnetite resource for a 10 Mtpa mine capacity over a mine life of approximately 20 years. The magnetite ore will be beneficiated on site to produce approximately 2.5 Mtpa of high grade magnetite concentrate for export through Port Lincoln or Port Spencer.

IronClad Mining Ltd: The company reported that ongoing resource definition drilling at the Wilcherry Hill Iron Ore project, about 40 km north of Kimba on northern Eyre Peninsula, is well underway to further delineate the near surface DSO for low cost mining and ore processing. IronClad Mining states that, in the current economic environment, reduced mining cost of the DSO, and the low cost of other materials suitable for upgrade by dry magnetic separation, will be economically beneficial for the Wilcherry Hill project.

5 Davies Tube Recovery (DTR) testing is a laboratory technique which uses a Davis Tube to recover magnetic particles from an ore samples. The per cent mass recovery of magnetic material is determined from the mass of sample recovered compared to the sample mass. The recovered magnetic and non-magnetic portions can be analysed for chemical composition (taken from Minotaur Exploration report explanatory notes).

Apollo Minerals Ltd: During 2011-12 year, the company reported an initial resource of 72 Mt grading at 25.9% Fe for the Sequoi deposit within its prospective Commonwealth Hill Iron Project, 90 km to the north of Tarcoola. The deposit is made up of 19.4 Mt at 27.7% Fe Indicated Resources and 52.6 Mt at 25.3% Fe Inferred Resources. Based on a recent ground magnetic survey, there is a potential expansion of the exploration target for the Sequoi deposit to between 100 and 150 Mt grading between 25 and 35% Fe.

New South Wales

Carpentaria Exploration Ltd: The company announced an increase in its Hawsons Iron Project present net value to \$3.2 billion following an update of a pre-feasibility study based on a mining optimisation study. The company states in its Annual Report that the mining option study includes revised mining production schedules, reduced stockpiles and in-pit crushing as well as using a conveying system instead of truck haulage. With a development partner, Carpentaria Exploration plans to launch the bankable feasibility study for Hawsons project this year, it expects to complete within two years. The Hawsons Iron Project, which is located 60 km southwest of Broken Hill, has current Inferred Resource of magnetite of approximately 1.4 billion tonnes at DTR grade of 15.5% Fe₃O₄ with a 12% cut-off grade.

Tasmania

Grange Resources Ltd: The company reported in early 2012 that it had a 75% increase in the mineral resources at its Southdown Magnetite Project 90 km from Albany, Western Australia. The 1.2 billion tonnes resource increase was the outcome of a definitive feasibility study resource definition drilling program. The company has also revised to 2015 for the anticipated start of the project but has maintained the production capacity of 10 Mtpa for a 14 year mine life. The company has also obtained the final major environmental permit for the project's desalination plant. The company says that with all major permits for the Southdown project in place, the project can initiate the development phase when the current market and economic environment improves.

Shree Minerals Ltd: A pre-feasibility study of the company's Nelson Bay River Iron Project 70 km southwest of Smithton, was completed and reported in early 2012 and confirmed the viability of the project. The company has identified three resource types, which include hematite DSO, Beneficiable low-grade goethite-hematite ore and magnetite ore. The company has reported DSO reserves of 0.33 Mt at 57.4% Fe.

Northern Territory

Sherwin Iron Ltd: An application for a mining lease for the Sherwin Creek Deposit C about 475 km southeast of Darwin was lodged by the company during 2012. The company states that ongoing pre-feasibility study infill drilling has resulted in the 100% upgrade of the Area C deposit Inferred Resources resulting in Indicated Resource of 18.3 Mt. Subject to a positive outcome of the project pre-feasibility study, Sherwin Iron anticipates producing an initial DSO of approximately 3 Mtpa from the Area C deposit.

Western Desert Resources Ltd: A total of five mining leases were granted for the Company's Roper Bar Iron Ore Project about 60 km south of Ngukurr and 50 km from the Gulf of Carpentaria coast. The company also achieved a Native Title Agreement with the Northern Land Council (NLC), Native Title Holders as well as a Load Facility Agreement with Mount Isa Mines Ltd which provides access to an area on Mount Isa Mines Mineral lease at Bing Bong in the Gulf of Carpentaria. Roper Bar Iron has a global mineral resource of 402 Mt at 40% Fe which includes a DSO grade component of 32.1 Mt at 56.8% Fe.

Queensland

Cerro Resources: The company has announced an updated Indicated Resource of 19.11 Mt at an average grade of 41.42% Fe and Inferred Resource of 11.40 Mt at 33.82% Fe for its Mount Philp Hematite Iron Prospect 54 km southeast of Mount Isa. Cerro Resources says that the deposit occurs as a single north-northeast trending iron-rich stratigraphic unit extending over 4 km within the Proterozoic Corella Formation and grades from hematitic quartzite through banded siliceous ironstone and siliceous ironstone into massive hematitic ironstone.

Australia Minerals and Mining Group Ltd: The company has reported an initial Inferred Resource of 6.1 Mt at 39.9% Fe at its Constance Range Iron Ore Project 'D' deposit which is located on the Qld/NT border 180 km northwest of Mount Isa.

Lithium

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Lithium (Li) is recovered from both mineral deposits, largely from the mineral spodumene ($\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$), and from salts, largely from lithium-rich brines in salt lakes. Lithium has a range of uses in both chemical and technical applications.

Lithium in various forms, e.g., as lithium carbonate, lithium hydroxide, lithium chloride, is used in lubricant greases, pharmaceuticals, catalysts, air treatment and particularly in batteries—both non-rechargeable (primary) lithium batteries and rechargeable (secondary) Li-ion batteries. Demand for lithium has expanded significantly in recent years as a result of its increasing use in rechargeable batteries for portable electronic devices, such as mobile phones, computers and rechargeable power tools, as well as in batteries and electric motors for electric bikes, hybrid and electric passenger cars, and other vehicles.

The major technical application for lithium is for production of ceramics and glasses, including heat-resistant glass and ceramics, e.g., oven wear and cook tops, as well as fluxes and glazes. Lithium is also used in its metal form in alloys, e.g., aluminium lithium alloy, magnesium lithium alloy, such as in the aerospace industry, taking advantage of the strong and light weight (low-density) characteristics lithium imparts.

For location of lithium deposits refer to Fig. 14 in the Tin chapter.

Resources

Australia's Economic Demonstrated Resources (EDR) are estimated to be 1006 kilotonnes (kt) of lithium in 2011, representing more than doubling of the 483 kt of lithium in 2010. All occur within hard rock pegmatite deposits. The bulk of Australia's lithium resources are in the Greenbushes' spodumene deposit, 250 kilometres (km) south of Perth, WA, and the bulk of the increase in Australia's EDR of lithium reflect a large increase of resources at this deposit. Greenbushes is the world's largest and highest grade spodumene deposit. Other EDR of lithium occur at Mount Marion about 40 km southwest of Kalgoorlie, Mount Cattlin, about 2 km north of Ravensthorpe, and Pilgangoora, 120 km south of Port Hedland, all in WA. Resources at Mount Marion amount to ~45 kt, resources at the Mount Cattlin deposit total ~70 kt, while resources at the Pilgangoora deposit total ~40 kt.

In 2011, Subeconomic Resources of lithium, all in the submarginal category and all in WA, total less than one kilotonne.

Inferred Resources of lithium total ~130 kt, an increase from the 90 kt in 2010; all are associated with the Greenbushes, Mount Cattlin, Mount Marion and Pilgangoora pegmatite deposits in WA, except for 4 kt in the Narraburra rare earth and rare metals project, 12 kilometres northeast of Temora, NSW.

Accessible EDR

All of Australia's EDR of lithium is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total lithium in Proved and Probable Ore Reserves as defined in the JORC Code. In 2011, JORC code reserves of 506 kt accounted for ~50% of Australia's Accessible Economic Demonstrated Resources (AEDR). This compares with JORC Code reserves of 174 kt in 2010. At Australia's 2011 rate of spodumene production, lithium reserves in the JORC Code categories are adequate for over 40 years.

Exploration

There are only a few companies exploring for lithium mainly in WA but no statistics are available on exploration expenditure.

Production

According to figures released by both Talison Lithium and Galaxy Resources Ltd, total production of spodumene concentrates for 2011 at the Greenbushes and Mount Cattlin Mines, WA, amounted to ~421 kt. This represents an increase of ~39% on 2010 production. Assuming a 6% Li₂O grade (true value between 4.8% and 7.5%), the 2011 production equates to ~11.7 kt of contained lithium.

World Resources

According to estimates by the United States Geological Survey (USGS) which have been modified by Geoscience Australia for Australia's resources, world lithium resources in 2011 totalled about 13 036 kt. The resource data does not include Canada. Chile holds approximately 7500 kt, or ~58% of the total world resources, followed by China with 3500 kt (~27%), Australia with 1006 kt (7.7%), and Argentina with 850 kt (6.5%).

Lithium resources occur in two distinct categories, lithium minerals and lithium-rich brines. Canada, China and Australia have significant resources of lithium minerals, while lithium brine is produced predominantly in Chile, followed by Argentina, China and the USA. Lithium brines are the dominant feedstock for lithium carbonate production. All Australia's current resources and production are from lithium minerals.

World production in 2011 was estimated by the USGS to be 34 kt of contained lithium, excluding the USA production for commercial reasons. Chile produced about 12.6 kt (~37%) to remain the world's largest producer in 2010 followed closely by Australia (34%), China (15%) and Argentina (~9%).

Industry Developments

According to various industries reports, the estimated global demand for lithium in 2011 was 130 000 tonnes of lithium carbonate equivalent (LCE), approximately 10% above the previous year. The primary growth in demand was in lithium batteries, glass and ceramics segments. Within the lithium battery sector, growth areas were in batteries for laptops, mobile phones, and other personal electronic devices. Demand for lithium in the electric vehicles (EV) segment is forecast to grow exponentially from 2014 onwards as major global car manufacturers launch new models to secure EV market share. The subsidies provided by some governments, including various legislations on fuel emissions, to promote less reliance on fossil fuels and a cleaner environment, is expected to encourage consumers to gradually move into hybrid/plugin hybrid or EVs.

China was the world's largest global consumer of lithium products in 2011, at 50 000 tonnes of LCE and was also one of the largest producers of lithium cathode materials for use in lithium-ion batteries.

In Australia, Talison Lithium Limited, the world's largest producer of hard-rock spodumene produces two categories of lithium concentrates at the **Greenbushes** Lithium Operations in WA:

- technical-grade lithium concentrates with low iron contents; and
- high yielding chemical-grade lithium concentrate used to produce lithium chemicals.

The company does not produce lithium chemical products, selling lithium concentrate instead to customers for processing into lithium chemicals, primarily lithium carbonate.

In late 2009 and through 2010, demand for Talison's technical-grade lithium concentrates rebounded strongly following a slowdown in early 2009, particularly in the glass sector from traditional markets such as Europe, the USA and Japan. The company also experienced a substantial increase in demand for its chemical-grade lithium concentrates, particularly from Chinese lithium chemical producers for use in lithium-ion battery industries. Consequently, both the company's chemical-grade plant and technical-grade plant have been operating at full capacity since July 2009.

Following completion of its Stage 1 expansion in December 2010, the total nameplate capacity at the Greenbushes operation increased to approximately 315 000 tonnes per annum (tpa) lithium concentrate. In early 2011, the company announced a further expansion to 740 000 tpa lithium concentrate involving a new purpose built chemical-grade production facility at a cost of about \$70 million. This plant was commissioned in the middle of 2012 and officially opened in August 2012. Talison is continuing to advance plans to develop a 20 000 tpa lithium-carbonate conversion plant in Australia to produce battery-grade lithium carbonate at a capital cost of between \$160 million and \$200 million.

Preliminary studies into the proposed plant were completed late 2011 with Kwinana, WA, chosen as the preferred location. Talison are currently undertaking an engineering study into the plant. An investment decision is expected by the end of 2012. In March 2011, the company reported a 157% increase in Proven and Probable lithium Reserves at Greenbushes to 31.4 million tonnes (Mt) grading 3.1% Li₂O with a combined Measured and Indicated Resource of 70.4 Mt grading 2.6% Li₂O. Based on these lithium mineral reserves, the mine life has been extended by 10 years to 22 years. Talison commenced additional resource drilling in the first half of 2012 with the aims of increasing lithium reserves and extending mine life.

During 2011, Galaxy Resources Limited (Galaxy) continued to ramp up production from the Dowling Pit at its **Mount Cattlin** lithium-tantalum mine (hard-rock spodumene) near Ravensthorpe in WA. The company mined 616 714 tonnes of ore grading 1.11% Li₂O producing 63 863 tonnes of spodumene grading 6.18% Li₂O. The company also produced 464 tonnes of tantalum concentrate grading 3.3% contained Ta₂O₅ with 234 tonnes containing ~6.85 tonnes Ta₂O₅ sold to Global Advanced Metals (GAM) under a long term agreement with Galaxy. When in full production, the Mount Cattlin project will produce 137 000 tpa of 6% Li₂O spodumene concentrate and ~25 tonnes of tantalite concentrate for an expected mine life of 16 years. Galaxy Resources Limited made its first shipment of 6500 tonnes of spodumene concentrate to China in March 2011 to its wholly-owned Lithium Carbonate Plant within the Yangtze River International Chemical Industrial Park in Jiangsu Province in China. Physical construction of the carbonate plant was completed in December 2011. The plant, commissioned in March 2012, with first production of lithium carbonate in April 2012, will produce 17 000 tonnes of battery grade lithium carbonate per year. Galaxy shipped a 10 tonne trial shipment of mica from its Mt Cattlin operation under a purchase agreement with a European international industrial minerals group that specialises in mica-based products. The company has commenced preliminary equipment design to achieve both the reduction of mica content in the final spodumene product and to produce a saleable mica by-product. In February 2011, the Mount Cattlin deposit had a reported JORC compliant resource of 18 188 kt at an average grade of 1.08% Li₂O and 156 grams per tonne (g/t) tantalum pentoxide (Ta₂O₅), containing an estimated 197 kt of Li₂O and 2845 tonnes of Ta₂O₅, based on a cut-off grade of 0.4% Li₂O. These figures include (at December 2011) inclusive JORC compliant Proven Reserves of 2803 kt at 1.09% Li₂O and 136 g/t Ta₂O₅ and Probable Reserves of 7933 kt at 1.03% Li₂O and 150 g/t Ta₂O₅. In March 2012, Talison announced its intention to merge with Canadian company Lithium One. The merger was approved by shareholders in June 2012 and completed in July 2012. The merger provides Galaxy with access to lithium resources in Canada and South America. In May 2012 Galaxy announced their first commercial sale of spodumene concentrate from Mt Cattlin to Chinese customers (for more than AUS\$5.5 million). In July 2012, operations at Mt Cattlin were temporarily stopped as the mine had a year's supply of spodumene feedstock stockpiled for Jiangsu operations.

Reed Resources Ltd (Reed: 70% ownership) and joint venture partner Mineral Resources Limited (Mineral resources: 30%) continue to advance the **Mount Marion** lithium project, 40 km southwest of Kalgoorlie, WA. Both companies have received approval for the final mining proposal from the Western Australian Department of Mines and Petroleum, allowing construction of the minerals processing plant at Mount Marion. Mine production is expected at an initial rate of 200 000tpa of 6% Li₂O chemical grade spodumene concentrate, containing about 12 000 tonnes of Li₂O. Currently it is envisaged that the mining will also produce 60 000 tpa of muscovite and 30 tpa of tantalite concentrate. The JV partners are evaluating the economics of producing by-product high-grade mica and have been in discussions with distributors and users of mica products. The Mount Marion deposit consists of a series of shallow dipping, parallel sheets of spodumene-bearing pegmatites within mafic-ultramafic volcanic rocks. The pegmatite sheets are more than 20 metres thick. The deposit has total contained resources of 14 867 kt at 1.3% Li₂O for a contained Li₂O resource of 200.5 kt, of which 48% are in Measured Resources (13.6%) or Indicated Resources (33%). The decision as to when mining operations will commence at Mount Marion is currently under review, having been delayed due to economic and financial market conditions, and the decision by Talison Lithium to significantly expand lithium production at the nearby Greenbushes mine. As part of the 30% ownership agreement, project development at the Mount Marion project is being fully funded by Mineral Resources. Reed and Mineral Resources are also currently evaluating down-stream strategies, such as the production of battery-grade lithium carbonate (Li₂CO₃) and a high purity lithium hydroxide product from spodumene concentrates produced at the Mount Marion lithium deposit. The companies completed a prefeasibility study (in June 2010) into the production of battery-grade lithium carbonate (Li₂CO₃). They are currently in preliminary discussions with third parties regarding both possible joint ventures for lithium carbonate production, as well as the possible partial sale of the spodumene operations.

The **Pilgangoora** Lithium project, 100% owned by Altura Mining Ltd (Altura), has been the site of extensive drilling throughout 2011-12, leading to revised (October 2012) total resources of 25 157 kt at 1.23% Li₂O for 310 kt of contained

Li₂O, of which 17 288 kt at 1.25% Li₂O for 219 kt of Li₂O are Indicated Resources. Lithium at Pilgangoora, 120 km south of Port Hedland in the Pilbara region of WA, is contained within spodumene within twelve outcropping to shallow spodumene-bearing pegmatites. The company is currently undertaking a pre-feasibility study expected for completion early 2013. Positive metallurgical studies of the spodumene ore have already been completed. Altura is currently undertaking or planning further drilling looking at deeper targets as well as converting resources into reserves.

Magnesite

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Magnesite (magnesium carbonate $MgCO_3$) is marketed in three main forms:

- crude magnesite, primarily for use in chemicals and agriculture;
- dead-burned magnesia, a durable refractory used in the cement, glass, steel and metallurgical industries; and
- caustic calcined magnesia, for use in making oxychloride and oxysulphate cements for flooring and wallboards, mouldings and acoustic tiles as well as various environmental and chemical applications.

Resources

Economic Demonstrated Resources (EDR) of magnesite remained unchanged in 2011 at 330 million tonnes (Mt). South Australia (SA) continued to have Australia's largest holding of EDR with 235 Mt, which is unchanged from 2006. The bulk of these resources occur as interbeds of sedimentary magnesite within the Skillogalee Dolomite at the Witchelina and Mount Hutton deposits, up to 30 kilometres (km) northwest of Leigh Creek. The average magnesite grade is 40% magnesium oxide (MgO).

Queensland (Qld) has Australia's second largest inventory with 63 Mt of magnesite EDR. The bulk of this resource occurs at Kunwarara, 70 km northwest of Rockhampton, where Queensland Magnesia Pty Ltd has global resources of 1200 Mt of magnesite-bearing material. Within this global resource, which has an Inferred Resource of 500 Mt of magnesite, several high-grade magnesite zones have been classified as EDR. The Kunwarara deposit occurs as sheet-like lenses of magnesite with an average thickness of 7.6 metres extending over about 63 square kilometres. It contains four high-grade zones of very high-density bone-type, low iron ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

The third largest inventory of EDR is in Tasmania (Tas) where the Arthur River deposit has a measured resource of 13.2 Mt with an average magnesite grade of 43.4% MgO. The resource is part of a much larger global resource of 195 Mt in the Arthur-Lyons River area, about 53 km south of Burnie.

The remainder of Australia's EDR occurs in the Winchester deposit 70 km south of Darwin in the Northern Territory (NT), at Thuddungra 80 km northwest of Young in New South Wales (NSW), and at Bandalup 20 km east of Ravensthorpe in Western Australia (WA).

Subeconomic Demonstrated Resources of 57 Mt of magnesite remained unchanged from 2006. All of these resources occur at Triple Four in central Qld and at Main Creek in northwest Tas.

Inferred Resources of magnesite remained unchanged in 2011 at 836 Mt with Qld accounting for 56%, followed by SA with 35% and Tas with 5%. The remaining resources are in NSW, the NT and WA.

Accessible EDR

All magnesite EDR is accessible for mining.

JORC Reserves

Joint Ore Reserves Committee (JORC) Code reserves comprise total magnesite in Proved and Probable Ore Reserves as defined in the JORC Code. In 2011, JORC Code reserves of 37.5 Mt (unchanged from 2010) accounted for approximately 11% of Accessible Economic Demonstrated Resources (AEDR). At Australia's 2010-11 rate of production, magnesite resources in the JORC Code reserves categories are adequate for almost 58 years.

Exploration

Data associated with exploration expenditure for magnesite are not published by the Australian Bureau of Statistics.

Production

The bulk of Australia's magnesite production was by Queensland Magnesia Pty Ltd which supplied high-grade electrofused and dead-burned magnesia to the global refractory market, as well as calcined magnesia for a wide range of applications. In 2010-11, the company produced a total of 644 325 tonnes of magnesite (275 819 tonnes in 2009-10). About 1647 tonnes of magnesite was produced from the Myrtle Springs region in SA in 2011.

World Ranking

According to Geoscience Australia and United States Geological Survey (USGS) data, Australia has about 4% of the world's EDR of magnesite, which total 8750 Mt. Russia, China and North Korea jointly account for almost 66% of the world's EDR. The Kunwarara deposit in Qld is the world's largest known resource of ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

According to USGS data, world production of magnesite totalled 20.65 Mt. The world's largest producers of magnesite in 2011 were China (69%), Russia (6%), Turkey (5%), and Austria (3%).

Industry Developments

Korab Resources Limited recently engaged Tenova Group's Bateman Engineering to conduct an update of a feasibility study completed by the Bateman/Multiplex consortium in 2001 on its **Winchester** deposit in the NT. The company is continuing investigation into being a supplier of magnesium oxide (MgO) based building products. MgO is used extensively in Canada, Asia and the USA to produce low-cost, high-strength building materials which do not expand or shrink when submerged in water or heated and are potential substitutes for fibro-board, plaster-board, chipboard and ceramic tiles. MgO-based products are fire-resistant to 1200 °C.

Beacon Hill Resources Plc through its subsidiary Tasmania Magnesite NL, holds mineral tenure over two large, high-grade magnesite deposits at **Arthur River** and **Lyons River** in northwest Tas. The company announced the results of a preliminary scoping study into the Arthur River project in the June quarter 2012. The study demonstrated a pre-tax nett present value of \$42 million based on a mine life of 17 years and a 292 000 dry tonnes per annum (tpa) operation producing on average 100 000 tpa of calcined magnesia.

The company is considering carrying out a full feasibility study, which would include the submission of a development proposal and environmental management plan to secure mining approval, the completion of the approved drilling program and the securing of a joint venture and/or off-take partners to fund the development of the project. The Arthur River deposit has a defined JORC compliant Measured Resource of 13 Mt of magnesite and an Inferred Resource of 10 Mt.

In 2010, Archer Exploration Limited through its wholly-owned subsidiary, Leigh Creek Magnesite Pty Ltd, acquired most of the magnesite deposits formerly owned by SAMAG. The deposits contained a combined JORC resource of 413 Mt with an average grade of 41.3% MgO. To develop its **Leigh Creek** magnesite deposits the company is seeking joint venture partners with technical and marketing expertise in magnesite, caustic-calcined magnesia and dead-burned magnesia.

Manganese Ore

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Manganese (Mn) is the twelfth most abundant element in the Earth's crust. Of approximately 300 minerals containing manganese, only about a dozen are of economic significance. The two main manganese minerals are pyrolusite (MnO_2) and rhodochrosite ($MnCO_3$). Manganese is the fourth most used metal in terms of tonnage after iron, aluminium and copper. Manganese is essential to iron and steel production by virtue of its sulphur-fixing, deoxidising and alloying properties. After its application in steel production, the most important market for manganese is dry cell batteries in the form of electrolytic manganese dioxide (EMD). It is an additive also in plant fertilisers and animal feed and as a colorant for bricks.

In Australia, there are three operating mines and one tailings re-treatment plant. The Woodie Woodie mine is located about 400 kilometres (km) south east of Port Hedland in Western Australia (WA). A manganese tailings processing plant also operates near the Woodie Woodie mine. The Northern Territory (NT) has two manganese mines, on Groote Eylandt in the Gulf of Carpentaria and at Bootu Creek 110 km north of Tennant Creek.

Manganese ore processing plants are operated by TEMCO at Bell Bay in Tasmania (Tas) and by Delta plc at Newcastle in New South Wales (NSW).

Resources

In 2011, Australia's Economic Demonstrated Resources (EDR) of manganese ore increased by 7% to 197 million tonnes (Mt), mainly because of a rise in EDR at Woodie Woodie (Table 10). Paramarginal Demonstrated Resources (PDR) remained unchanged at 23.1 Mt and Subeconomic Demonstrated Resources (SDR) also remained unchanged at 167 Mt. Inferred Resources increased by 136% to 313 Mt, mainly because of the announcement of an Inferred Resources increase at the Butcherbird Manganese Project in WA.

Table 10. Resources of manganese ore in the States and Northern Territory.

	Demonstrated Economic (Mt)	Demonstrated Paramarginal (Mt)	Demonstrated Submarginal (Mt)	Inferred Undifferentiated (Mt)
Queensland	0	0	0	0.2
Western Australia	46.1	23.1	167.0	262.6
Northern Territory	151.3	0	0	50.0
Total	197.4	23.1	167.0	312.8

Accessible EDR

All manganese ore EDR (197.4 Mt) is accessible. The resource life (resource to production ratio) is about 14 years at current rates of production of beneficiated manganese ore.

JORC Reserves

Manganese ore Joint Ore Reserve Committee (JORC) Code reserves are 143 Mt (72% of accessible EDR). The resource life based on JORC reserves, and at the current rate of production of beneficiated manganese ore, is about 10 years.

Exploration expenditure

Data associated with exploration expenditure for manganese are not published by the Australian Bureau of Statistics on either a State or National basis.

Production

The Bureau of Resources and Energy Economics (BREE) reported that Australia produced 6.96 Mt of beneficiated manganese ore in 2011 (6.5 Mt in 2010). The total tonnage of manganese ore mined is approximately twice the tonnage of beneficiated manganese ore produced (reported by BREE) because of yields of around 50% after beneficiation. Exports of manganese ores for 2011 totalled 6.9 Mt valued at \$1369 million compared to 5.5 Mt valued at \$1509 million in 2010.

World ranking

Australia has 12% of the world's EDR of manganese ore and is ranked fifth behind the Ukraine (25%), South Africa (20%), Brazil (15%) and China (13%). Australia produces 17% of the world's manganese ore and is ranked second behind China (34%).

Industry Developments

Northern Territory

GEMCO: In 2011, GEMCO approved the US\$279 million Phase 2 Expansion at its Groote Eylandt operation. This will increase the beneficiated manganese capacity at Groote Eylandt to 4.8 million tonnes per annum (Mtpa) from 4.2 Mtpa. First JORC estimates for the eastern leases were reported as part of further exploration intended to extend the life of the mine.

OM Holdings Ltd: The company's Bootu Creek plant has the capacity to produce 1 Mtpa annually, and 2011 resulted in record annual production of 902 kilotonnes (kt) which represents an increase 8.5% on 2010. Renner Springs, which is 70 km northwest of the Bootu Creek project, has undergone exploration and had its first JORC Inferred Resource estimate reported in 2011.

Western Australia

Consolidated Minerals Ltd: During 2011, the Woodie Woodie mine produced 3.2 Mt of manganese ore, a 14% increase on production for 2010. Exploration activities were positive, with a large increase in the mineral resource inventory. The Woodie Woodie product has high manganese content and very low phosphorus, while having very low degradation and high thermal stability.

Mineral Resources Ltd: The Nicholas Downs manganese project increased production capacity to 720 ktpa in 2011, with 449 kt exported from both Woodie Woodie operations at Peak Hill sites and the Nicholas Downs project.

Mesa Minerals Ltd: The Ant Hill and Sunday Hill projects are located 400 km south of Port Hedland. Both mines remained on care and maintenance throughout 2011.

Montezuma Mining Company Ltd: The Butcherbird Manganese project is located 120 km south of Newman. In 2011, the first JORC estimates were reported for eight deposits in the project, with a global Inferred Resource of 119 Mt reported, and a lower grade Inferred Resource of 55.9 Mt. A scoping study was conducted to investigate the development of a mine with capacity to produce up to 1 Mtpa.

Mineral Sands

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The principal components of heavy mineral sands are rutile (TiO_2), ilmenite (FeTiO_3), zircon (ZrSiO_4) and monazite ($[(\text{Ce},\text{La},\text{Th})\text{PO}_4]$). Also present are minor amounts of xenotime ($\text{Y}(\text{PO}_4)$) - a yttrium-bearing phosphate hosting 54 to 65% REO, and comprising other REE such as erbium and cerium, and thorium. Rutile, ilmenite, leucoxene (an alteration product of ilmenite) are used predominantly in the production of titanium dioxide (TiO_2) pigment. The titanium-bearing minerals rutile and leucoxene are sometimes blended to produce HiTi (High grade titanium with a TiO_2 content of 70% to 95%) which is used as a feedstock to produce titanium dioxide, make titanium metals for the aerospace industry and in the manufacture of welding rods. Less than 4% of total titanium mineral production, typically rutile, is used in making titanium sponge metal. Zircon is used as an opacifier for glazes on ceramic tiles, in refractories and for the foundry industry. Recently there has been renewed interest in monazite as a source of thorium for possible use to generate electricity in thorium nuclear reactors.

Resources

Economic Demonstrated Resources (EDR) of ilmenite decreased by 5.3% to 188.9 million tonnes (Mt) in 2011, down from 199.5 Mt in 2010. About 45.7% of Australia's EDR of ilmenite is in Western Australia (WA) and 19% is in Queensland (Qld) with Victoria (Vic) containing 21.8%, New South Wales (NSW) 10.3% and South Australia (SA) 3.1%.

EDR of rutile, which includes some leucoxene in WA, increased by 15.7% to 27.2 Mt in 2011 from 23.5 Mt in 2010. Victoria has the largest share of Australia's rutile EDR with 42.3% followed by Qld (19.9%), WA (19.1%), NSW (16.5%) and SA (2.2%).

EDR of zircon increased from 39.4 Mt in 2010 to 46.6 Mt in 2011 with Vic (33.8%), WA (29.9%) and Qld (16.5%) accounting for most of Australia's zircon EDR. The balance was in SA (11.8%) and NSW (7.8%).

Australia's Subeconomic Demonstrated Resources of ilmenite, rutile and zircon in 2011 amounted to 30.3 Mt of ilmenite, which was a decrease of 21.9% on 2010, 0.6 Mt of rutile, a decrease of 91.5% on the previous year, and 1.3 Mt of zircon, a decrease of 87.5% on the 2010 figure.

Inferred Resources of ilmenite increased by 41.9% in 2011 to 182.1 Mt. Victoria has the largest proportion of inferred ilmenite resources with 48.1% of the Australian total followed by NSW (15.2%), WA (21.2%) and Qld (8.7%).

Inferred Resources of rutile increased to 40.2 Mt from 30.1 Mt in 2010. Victoria has the largest share of Australia's inferred rutile resources with 62.9% of the Australian total followed by NSW (22.7%), SA (4.8%), Qld (4.7%) and WA (4.7%).

Inferred Resources of zircon increased to 62.1 Mt from 34.9 Mt in 2010. Victoria is the main holder of zircon Inferred Resources with 74.9% of the Australian total, followed by NSW (10.9%), WA (4.9%) and Qld (4.7%).

Accessible EDR

A significant portion of mineral sands EDR is in areas quarantined from mining because they are largely incorporated in national parks and other areas with restricted access to mining. Geoscience Australia estimates that around 17% of ilmenite, 12% of rutile and 14% of zircon EDR is unavailable for mining. Deposits in this category include Moreton Island, Bribie Island and Fraser Island, the Cooloola sand mass, the Byfield sand mass and the Shoalwater Bay area in Qld and the Yuraygir, Bundjalung, Hat Head and Myall Lakes National Parks in NSW.

JORC Reserves

About 27% of Australia's ilmenite Accessible EDR (AEDR), 27% of rutile AEDR and 34% of zircon AEDR comprise Reserves as defined under the Joint Ore Reserve Committee (JORC) Code. The remaining AEDR represents resources assessed by Geoscience Australia from the Measured and Indicated categories of industry-reported mineral resources as defined under the JORC Code, and other classification systems used by companies not listed on the Australian Securities Exchange.

About 83% of Australia's ilmenite AEDR, 76% rutile AEDR and 73% zircon AEDR comprises published JORC Code compliant Measured and Indicated Resources. Some of these resources are in deposits of operating mines and mines

being developed as well as in deposits that have published scoping/feasibility studies with positive results and deposits that are of comparable size and grade to those being mined elsewhere in Australia. It is not possible to make a more detailed analysis of these resources on an individual deposit scale because of a lack of resource data.

Duration of Resources

At the rate of production in 2011, Australia's AEDR of ilmenite, rutile and zircon is sufficient for an average of 122 years for ilmenite (127 years in 2010), 50 for rutile (47 years in 2010) and 53 for zircon (61 years in 2010). However, resources in the JORC Code reserves categories are adequate for only 33 years for ilmenite (22 years in 2010), 14 for rutile (11 years in 2010), and 18 for zircon (16 years in 2010). Variations in resource life of the three commodities are based on the AEDR and are the result of changing levels of production. For example, lower production in response to a fall in demand because of global recessions may create the impression of an increase in resource life, but is not necessarily indicative of an increase in resources. Such trends may be reversed with resumption of demand and, as a consequence, represent snapshots of the resource life at that time.

Exploration

Expenditure on exploration for mineral sands has not been available since 2010.

Production

In 2011, Australia produced 1.277 Mt of ilmenite, 474 000 tonnes of rutile, 225 000 tonnes of leucoxene and 762 000 tonnes of zircon compared with 1.313 Mt of ilmenite, 430 000 tonnes of rutile, 160 000 tonnes of leucoxene and 540 000 tonnes of zircon in 2010. About 1.973 Mt of ilmenite, 388 000 tonnes of rutile and 963 000 tonnes of zircon was exported in 2011, with exports exceeding production for ilmenite and zircon in 2011. Australia also produced 526 000 tonnes of synthetic rutile in 2011 compared with 557 000 tonnes in 2010.

According to Iluka Resources Ltd⁶, the global zircon demand in the first half of 2012 remained soft with larger inventories of ceramic finished goods in China and a weak European market. The demand for high grade titanium dioxide was high in the first quarter in 2012 but softened in the second quarter.

World Ranking

According to Geoscience Australia and the United States Geological Survey data, Australia's EDR of rutile and zircon represent the world's largest economic resources in 2011 with 53%, and 50%, respectively. Australia also has the second largest share of the world's ilmenite with 15%, behind China, which has 31%. Other major country rankings include India (13%), South Africa (10%) and Brazil (7%) for ilmenite, South Africa (16%) and India (14%) for rutile and South Africa (23%) and Ukraine (7%) for zircon.

During 2011, world production of ilmenite increased by 7.8% to 11 Mt, rutile increased by 6.3% to 773 000 tonnes and zircon increased by 16.6% to 1.45 Mt. Australia is the largest producer of rutile with about 61.3% of the world production followed by South Africa with 16.9% and Sierra Leone with 7.8%. Australia is the third largest producer of ilmenite with 11.1% after South Africa with 17.8% and Canada with 12.1%, and is the largest producer of zircon with 52.6% followed by South Africa with 26.2% and China with 6.9%.

Industry Developments

Companies which produced heavy mineral sands during 2011 were Iluka Resources Ltd, Bemax Resources Ltd, Tiwest joint venture and Doral Mineral Sands Pty Ltd, all in WA, and Sibelco Australia Ltd in Qld. Iluka Resources and Bemax Resources also produced heavy minerals in the Murray Basin in Vic and NSW and at the Matilda Zircon Limited deposits on the Tiwi Islands off the Northern Territory.

Iluka Resources' heavy mineral sand operations in WA are located in two regions, the mid-west region north of Perth and in the State's southwest region south of Perth.

⁶ D. Robb, Managing Director, Iluka Resources Ltd, 2012. 2012 Half year results. Presentation slide pack, 23 August 2012.

The coastal mid-west region comprises the main mines of **Eneabba** (two wet concentrators, five mining units). The region includes the company's Narngulu facility at Geraldton comprising mineral separation, zircon finishing and two synthetic rutile kilns (SR kilns 3 and 4) as well as port operations and storage facilities at Geraldton. Iluka Resources has upgraded its Narngulu plant to process heavy mineral concentrates (HMC) from its **Jacinth-Ambrosia** mine in the Eucla Basin in SA.

Another mineral separation plant, SR kilns 1 and 2 are located at North Capel in the southwest region of WA, which also hosts Iluka Resources heavy minerals mine at **South Tutunup**.

During 2011, Iluka Resources recommenced mining at Eneabba at the **Twin Hills** and **Hill North** deposits. A pre-feasibility study for the proposed **Cataby** mine development in the mid-west region approximately 150 kilometres north of Perth progressed during the year. The **Gingin** mine in mid-west was closed in 2010 and was undergoing rehabilitation in 2011. Zircon production from the southwest region was transported to Narngulu in the mid-west. Mining continued at the Tutunup South deposit which provides HMC for the mineral separation plant at North Capel.

The SR kiln 2 in the southwest restarted operations after planned maintenance and a trial parcel of 10 000 tonnes of ilmenite from Iluka Resources mining operations in Virginia, USA, was passed through the SR kiln 3 in the mid-west.

In 2011, production of heavy mineral sand commodities from Iluka Resources mining and processing activities in WA, now referred to as the Perth Basin, amounted to 99 700 tonnes of upgradeable ilmenite (upgradeable to synthetic rutile), 285 700 tonnes of synthetic rutile and 9300 tonnes of zircon.

In the Eucla Basin in SA, Iluka Resources operates the Jacinth-Ambrosia mine and owns the **Tripitaka**, **Typhoon**, **Atacama** and the newly discovered **Sonoran** deposits. Production from the Jacinth-Ambrosia mine during 2011 amounted to 313 700 tonnes of zircon, 56 400 tonnes of rutile and 171 600 tonnes of saleable ilmenite and 2700 tonnes of upgradeable ilmenite. The heavy mineral concentrates from the Jacinth-Ambrosia mine are transported 270 km by road to the Port of Thevenard near Ceduna, SA before being sent about 2500 km by sea to Geraldton for mineral separation at Iluka Resources upgraded Narngulu Plant 2 in the mid-west region. On 28 January 2011, Iluka Resources announced resources for its Sonoran deposit as 30.1 Mt grading at 7.3% heavy minerals with a heavy mineral assemblage comprising 67% ilmenite, 17% zircon and 2% rutile at a heavy mineral cut-off grade of 3%. The Sonoran deposit is similar to Atacama but differs from the Jacinth-Ambrosia deposit in that it contains a zircon component in the heavy mineral concentrate of around 15% which compares with around 50% for the Jacinth-Ambrosia deposit.

Iluka Resources operates a mineral separation plant at Hamilton, Victoria, to produce the final specification rutile and zircon. The mineral separation plant processes feedstock from the **Douglas** project near Horsham in western Vic. and from the Murray Basin Stage 2 development at **Kulwin**, 30 km west of Ouyen in northwest Vic. Mining and concentration operations at Douglas were completed in the first half of 2012.

Iluka Resources reported in its June 2012 quarterly report that mining operations were interrupted during the first half of 2012 by a mine move from the Kulwin deposit to the **Woorneck**, **Rownack**, **Pirro** (WRP) deposits, approximately 25 km away. After a successful plant relocation from Kulwin, commissioning of the WRP mining unit and wet concentrator commenced mid April with HMC production commencing in early May 2012.

Another group of deposits are located at Euston in NSW named **Castaway**, **Kerribee**, **Earl**, **Dispersion** and **Koolaman**.

Production from the Murray Basin operations in 2011 totalled 224 900 tonnes of rutile, 99 500 tonnes of upgradeable ilmenite and 218 200 tonnes of zircon.

In 2011, Iluka Resources continued a pre-feasibility study for the **Balranald** project. The Balranald project comprises the deposits of **West Balranald** and **Nepean** in southwest NSW. The deposits are large, but also deeper than other deposits which Iluka Resources has mined in the Murray Basin. The Balranald deposit contains approximately 14.5 Mt of heavy mineral resources, with rutile assemblages ranging from 12% to 15%. The pre-feasibility study is expected to take two years will include evaluation of various mining methods, ground water management studies, engineering options, and transport and logistics studies. Production is planned to commence in 2015⁷.

The heavy mineral resources/reserves held by Bemax Resources (a controlled entity of Cristal Australia Pty Ltd) are located in old shorelines in two provinces, the Murray Basin in Vic and NSW, and the southwest region of WA. The company's operations in the Murray Basin include the **Ginkgo** and **Snapper** mines and a mineral separation plant at Broken Hill in western NSW.

Bemax Resources last reported in 2009 that its total resource in the Murray Basin amounted to 95.1 Mt of contained heavy mineral. Bemax no longer publishes its resources for individual deposits and regions and the resources for the Murray Basin in 2010 are not known.

Production from Bemax Resources Ginkgo and Snapper mines in 2011 totalled 239 355 tonnes of ilmenite, 32 564 tonnes of zircon and 84 863 tonnes of rutile⁸. Bemax Resources reported that resource drilling at **Atlas-Campaspe** and **Crayfish** deposits was completed in 2011.

Bemax Resources heavy mineral sand mining in the southwest region of WA continued at **Gwindinup**, about 30 km south of its mineral separation plant at Bunbury. The company reported in its March 2012 quarterly report that development of the **Wonnerup** mine is continuing⁹. Heavy mineral production from Bemax Resources operations in the southwest region in 2011 amounted to 124 158 tonnes of sulphate and secondary ilmenite and leucoxene and 9958 tonnes of zircon.

The heavy mineral sand mines on **North Stradbroke** island, are owned by Sibelco Australia Limited. There has been no published information on the production of heavy minerals or resources of heavy minerals since 2008.

Australia Sands, a wholly owned subsidiary of Exxaro Resources Ltd, has as a principal asset 50% ownership in the Tiwest Joint Venture with Tronox Incorporated. Tiwest operates an integrated titanium dioxide project in WA incorporating a dredging and dry-mining heavy mineral sands operation at **Cooljarloo**, dry separation and synthetic rutile plants at Chandala and a titanium dioxide pigment plant at Kwinana. Production in 2011 was approximately 452 000 tonnes of ilmenite, 64 000 tonnes of zircon, 38 000 tonnes of rutile, 20 000 tonnes of leucoxene, 180 000 tonnes of synthetic rutile and 152 000 tonnes of TiO₂ pigment. On 26 September 2011, Exxaro Resources and Tronox Incorporated announced that New Tronox will acquire Exxaro Resources mineral sands operations, which includes Exxaro Resources 50% interest in the Tiwest joint venture with Tronox Incorporated, along with 74% of the Exxaro Resources KZN Sands and Namakwa Sands operations in South Africa, in exchange for a 38.5% shareholding in New Tronox.

Matilda Zircon Ltd's **Leithbridge South** deposit was developed over the 2010-11 wet season but a fire in June 2011 damaged the concentrator and pre-concentrator which had to be rebuilt. This resulted in mining of the deposit being delayed until early 2012. Production recommenced in the first half of 2012 and mining at Leithbridge South will be completed by November 2012. Matilda Zircon also entered into a strategic alliance with Doral Pty Ltd under which Doral provided Matilda Zircon with US\$4.5 million to complete a feasibility study of the **Keysbrook** heavy mineral project in southwest WA. The Keysbrook mine is expected to have a life of eight years. On 19 July 2012, Matilda Zircon reported that it was planning to commence construction at Keysbrook in early 2013 and begin production in late 2013¹⁰. On 4 September 2012, Matilda Zircon Ltd changed its name to MZI Resources Ltd.

Gunson Resources Ltd released a definitive feasibility study in January 2010 on its **Coburn** heavy mineral sand deposits south of Geraldton in WA. The study considered a mine life of 23.5 years with annual production rates of 40 000 tonnes of zircon, 90 000 tonnes of ilmenite, 9000 tonnes of rutile and 7000 tonnes of leucoxene. The company reported that in 2011, the net present value for the project increased substantially to \$223.7 million from \$139 million as the prices of zircon and titanium dioxide minerals increased, in some cases to more than double those prevailing in early 2010. Gunson Resources announced on 13 August 2012 that the board of a major Korean steel producer, POSCO, had approved investment in Gunson Resources Coburn zircon project¹¹. Under the agreement, POSCO's special purpose investment vehicle (SPV) will earn 40% interest by making a \$7 million initial payment to Gunson Resources and then contributing the first \$21 million of Gunson Resources share of mine development expenditure. POSCO investment in the project is contingent on Gunson Resources raising its 60% equity share of the mine development costs, less the \$28 million earn-in expenditure by the POSCO SPV, by the end of 2012.

8 Bemax Resources Ltd, 2012. December 2011 Quarterly Report. 3pp.

9 Bemax Resources Ltd, 2012. March 2012 Quarterly Report. 3pp.

10 Gunson Resources Ltd, 2012. Keysbrook leucoxene zircon project. Australian Securities Exchange release, 19 July, 2012. 4pp.

11 Gunson Resources Ltd, 2012. POSCO to invest in Coburn zircon project. Australian Securities Exchange release, 13 August, 2012. 1pp.

In March 2012, Gunson Resources announced that it had reached agreement for an ilmenite sales contract with the world's largest manufacturer of titanium dioxide, E.I. du Pont de Nemours and Company (DuPont), owner of DuPont Titanium Technologies. The agreement is for DuPont to take Gunson Resources proposed share of chloride ilmenite production from Coburn over a five year period. Gunson Resources also noted that it was seeking off-take partners for the higher titanium dioxide mineral products (rutile and leucoxene combined into a 90% TiO₂ HiTi product) and zircon.

Image Resources NL holds heavy mineral sand resources in the North Perth Basin and in the Eucla Basin, WA. Image Resources reported that in March 2012 it had commenced a detailed review of the August 2011 scoping study to determine the basis of design for a feasibility study and to confirm the project development schedule. The feasibility study is scheduled to be completed by the first quarter of 2013¹².

Image Resources also released a resource figure for its **Cyclone Extended** deposit in the Eucla Basin amounting to 86.3 Mt of Indicated and Inferred Resources containing 1.638 Mt of heavy minerals at a cut-off of 1% heavy minerals containing 345 000 tonnes of zircon, 154 700 tonnes of rutile, 617 800 tonnes of HiTi (70%-95% TiO₂) and 395 700 tonnes of altered ilmenite (55%-70% TiO₂)¹³. The Cyclone Extended deposit forms a southeast extension of the **Cyclone** deposit.

In March 2012, Diatreme Resources Ltd released results of a prefeasibility study on its Cyclone heavy minerals deposit in the Eucla Basin together with a prefeasibility study pit design which enclosed a Probable Ore Reserve of 97 Mt at 2.5% heavy mineral cut off containing 2.4 Mt heavy minerals, including 770 000 tonnes of zircon. The prefeasibility study indicated a potential to mine 10 million tonnes per annum (Mtpa) of ore yielding approximately 147 000 tonnes of HMC producing 65 000 tonnes of zircon, 10 000 tonnes of HiTi87 (86.6% TiO₂) and 46 000 tonnes of HiTi67 (67.3% TiO₂). The ore reserve is contained within a Measured and Indicated Resource of 136 Mt of ore at 2.3% heavy minerals containing 3.1 Mt of heavy minerals grading 31% zircon, 3% rutile, 6% leucoxene (85-95% TiO₂), 21% HiTi (70-85% TiO₂) and 23% altered ilmenite (<70% TiO₂)¹⁴.

Astron Ltd's Donald project in the Murray Basin in Vic comprises the **Donald** (WIM 250) and **Jackson** (WIM 200) deposits located 240 km west-north-west of Melbourne. On 1 December 2011, the company announced Measured, Indicated and Inferred Resource for the deposits totalling 2630 Mt grading at 5.3% heavy minerals. The heavy mineral concentrate was reported to grade at 19% zircon, 33% ilmenite, 7% rutile and 12% leucoxene. Astron Ltd reported that the zircon content amounted to about 37 Mt. These resources are located within a larger resource totalling Measured, Indicated and Inferred Resources at 4040 Mt grading at 4.8% heavy minerals¹⁵.

In June 2012, Astron Ltd announced Proved and Probable Reserves within the Donald project totalling 461 Mt at 5.9% heavy minerals, which equates to about 27.199 Mt of heavy minerals at about 18.6% zircon, 33.9% ilmenite, 18.6% leucoxene and 6.8% rutile¹⁶. Astron Ltd also reported that it engaged an independent technical consultant to conduct a review of the company's proposed hot acid leaching process designed to reduce the level of uranium and thorium in its Donald zircon product from around 1000 parts per million (ppm) to around 500 ppm and minimize impurities such as iron, titanium, aluminium and phosphorus. The project is planned to be a 7.5 Mtpa mining operation producing 0.5 Mtpa of heavy mineral concentrate for export to China. The review concluded that there are no flaws in the process to produce a saleable zircon product.

On 28 August 2012, Sheffield Resources Ltd announced Measured, Indicated and Inferred Resources for its **West Mine, Yandanooka, Durack** and **Ellengail** deposits in the Eneabba region north of Perth, WA, totalling 226 Mt grading at 2.3% heavy minerals amounting to 5.29 Mt of heavy minerals¹⁷. The heavy mineral concentrate is estimated to grade at 11% zircon, 6.7% rutile, 6.4% leucoxene and 63.5% ilmenite.

On 3 September 2011, Sheffield Resources also announced a new discovery from drilling at its Dampier heavy mineral sand project near Derby in the Kimberley Region of WA. The **Thunderbird** discovery is the first target drilled by Sheffield Resources within the Dampier heavy mineral sand project area. Results from the first 24 holes, which represents about 14% of Sheffield's first drilling program, returned mineralised intervals of up to 42 metres (m) in width,

12 Image Resources NL, 2012. Quarterly report for the quarter ended 30 June 2012. 7pp.

13 Image Resources NL, 2011. Annual Report 2010. 60pp.

14 Diatreme Resources Ltd, 2012. Exploration activities report. Quarter ended 31 March 2012. Australian Securities Exchange release. 8pp.

15 Astron Ltd, 2011. Donald mineral sands project – resource update. Australian Securities Exchange release 1 December 2011. 3pp.

16 Astron Ltd, 2012. Donald mineral sands project – review of uranium/thorium wash process and proved ore reserve update. Australian Securities Exchange release 18 June 2012. 4pp.

17 Sheffield Resources Ltd, 2012. Eneabba project resource inventory exceeds 5Mt heavy mineral. Australian Securities Exchange release, 28 August 2012. 11pp.

some of the intersections published by Sheffield Resources include:

- 33 m at 6.3% heavy minerals (HM) from surface (THAC022), including 21 m at 8.9% HM from surface;
- 42 m at 6% HM from 6 m (THAC006), including 25.5 m at 8.2% HM from 12 m;
- 40.5 m at 6.5% HM from 13.5 m (THAC024), including 25.5 m at 8.6% HM from 19.5 m; and
- 20.5 m at 9.5% HM from 24 m (THAC013).

The project occurs over the Canning Basin and may represent a new unexplored heavy mineral province. Other companies exploring the area include Iluka Resources Ltd and Diatreme Resources Ltd.

On 15 May, Crossland Uranium Mines Limited reported resources for an inland placer deposit, the **Charley Creek** deposit, containing zircon, monazite and xenotime (YPO₄). The company reported that the deposit is an alluvial outwash which comprises an Indicated Resource of 387 Mt containing 27 000 tonnes of xenotime, 161 000 tonnes of monazite and 196 000 tonnes of zircon. The xenotime and monazite were stated to contain about 14 000 tonnes of total rare earth oxides (REO). In addition, another 418 Mt of Inferred Resources was reported to hold about 121 000 tonnes of REO in about 31 000 tonnes of xenotime and 167 000 tonnes of monazite as well as 220 000 tonnes of zircon¹⁸. An earlier report by Crossland dated 5 April 2012 stated that the equivalent monazite in the HMC (calculated from chemical analyses) is 87 372 grams per tonne (g/t) and equivalent xenotime is 8310 g/t while the HMC in the alluvium was 2.54%¹⁹.

Metallica Minerals Limited's wholly-owned subsidiary, Oresome Australia Pty Ltd, reported that it had commenced the permit and statutory approval process for its **Urquhart Point** heavy mineral sands project in Cape York, Qld. The company has contracted work for an Environmental Impact Statement and a bankable feasibility study on the project²⁰. The Urquhart Point deposits are approximately 5 km southwest of Weipa on the Gulf of Carpentaria, Qld. The zircon and rutile deposit has an Indicated Resource of 2.8 Mt at 7% heavy mineral sands to a maximum depth of three metres. On 26 April 2012, Metallica also announced an Inferred Resource for its **Glenaladale-Stockdale** deposit in east Gippsland, Vic amounting to 1700 Mt of ore grading 2.2% heavy minerals with a heavy mineral content of 38 Mt. An Inferred Resource of 360 Mt within the larger resource was reported as grading 2.7% heavy minerals containing 9.7 Mt heavy minerals, including 1.42 Mt zircon, 0.4 Mt rutile, 4.76 Mt combined titanium minerals and 60 000 tonnes monazite.

On 2 August 2011, Astro Resources NL reported that it had secured the rights to acquire the majority share in a heavy mineral sand project located in southwest WA, including the **Warner Glen** and **Rover Range** deposits. Astro reported that, in 1994, BHP estimated an Indicated Resource of 106 Mt of 2.82% ilmenite grading 0.06% zircon for the Warner Glen deposit and stated that the Rover Range has an additional JORC Code compliant Inferred Resource of 701 Mt of 2.6% ilmenite²¹.

18 Crossland Uranium Resources Ltd, 2012. Quarterly report for period ended June 30, 2012, 5pp.

19 Crossland Uranium Resources Ltd, 2012. Announcement to the Australian Securities Exchange 5 April 2012, 3pp.

20 Metallica Minerals Ltd, 2011. Annual Report, 40pp.

21 Astro Resources NL, 2011. Astro to acquire major new resource project. Announcement to the Australian Securities Exchange 2 August, 8pp.

Molybdenum

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Molybdenum (Mo) is used mostly in steels and superalloys to enhance strength, toughness, thermal and corrosion resistance, and to reduce brittleness. Applications include high speed steels, stainless steels (especially to increase corrosion resistance), high temperature steels and in cast iron. It is used also in nickel, titanium and molybdenum base alloys for applications requiring high strength and stability at high temperatures such as heating elements, radiation shields, glass melting equipment and in jet and rocket engines. Other uses include as catalysts, lubricants and pigments, as well as applications in the electronics industry and as trace nutrients in fertilisers. The main commercial source of molybdenum is the mineral molybdenite (MoS_2) but it is found also in minerals such as wulfenite (PbMoO_4) and powellite (CaMoO_4). Molybdenum is mined as a principal ore but is more commonly recovered as a by-product or co-product from copper and tungsten mining.

Resources

Australia's Economic Demonstrated Resources (EDR) of molybdenum decreased from 324 kilotonnes (kt) in 2010 to 167 kt in 2011. This decrease results from the reclassification to Paramarginal status of 220 kt of reserves at the Spinifex Ridge Molybdenum-Copper Project deposit in Western Australia (WA) which the owner, Moly Mines Limited, indicates is not currently economic. Spinifex Ridge is Australia's largest molybdenum deposit. The reduction in Australia's total EDR was partly offset by increases in new economic resources at Aeon Metals Limited's Whitewash Project in Queensland (Qld) and Dart Mining's Unicorn deposit in Victoria (Vic). The majority of Australia's EDR is in Qld with 87%, followed by Vic with about 9% (57% in WA, followed by 38% in Qld, if the Spinifex Ridge Molybdenum-Copper Project resources are included). Prior to 2011, the majority of Australia's EDR was in WA (Spinifex Ridge deposit).

Australia's Subeconomic Demonstrated Resources (SDR) accounted for about 88% of the total Demonstrated Resources, with 75% of SDR in Qld and the remainder in WA. In 2011, Paramarginal Resources and Submarginal Resources stood at 1220 kt and 0.5 kt respectively.

Inferred Resources of molybdenum increased from 514 kt²² in 2010 to 562 kt in 2011, largely as a result of increased resources at the Anthony deposit in Qld. Queensland and WA account for 65% and 28% of Inferred Resources respectively.

Accessible EDR

All of Australia's EDR of molybdenum is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total molybdenum in Proved and Probable Ore Reserves as defined in the JORC Code. In 2010, JORC Code reserves of 220 kt (unchanged from 2009) accounted for approximately 68% of Accessible Economic Demonstrated Resources (AEDR). All of these reserves were from the Spinifex Ridge Molybdenum-Copper Project deposit in WA. As reported by Moly Mines Ltd, the current molybdenum price makes this deposit uneconomic, resulting in the JORC Code reserves for 2011 being zero.

Exploration

Data on exploration expenditure for molybdenum are not available nationally.

Production

There was no molybdenum production in Australia in 2011.

22 Revised downward from 607kt figure reported in 2011 AIMR Report.

World Ranking

According to United States Geological Survey (USGS) data, updated by Geoscience Australia for Australia's resources, world economic resources of molybdenum in 2011 are estimated to be about 10 100 kt with China holding 43% of the resources followed by the USA with 27% and Chile with 12%. Australia accounts for just over 1.5% of the world's economic resources of molybdenum.

The USGS estimates that world molybdenum production in 2011 amounted to 250 kt compared with 242 kt in 2010. China, the USA, Chile and Peru accounted for about 86% of global outputs in 2011 with China producing 94 kt, followed by the USA with 64 kt, Chile with 38 kt and Peru with 18 kt.

Industry Developments

World molybdenum prices soared in 2007, reaching a high of US\$38 per pound (lb) in September 2008 from a low of about US\$5/lb in 2001. After the global financial crises in October 2008, the averaged price declined sharply to US\$8/lb and continued at that level through the first half of 2009. This led to a tightening of global supplies as many companies ceased operation. However, increased demand from China, Japan and Korea resulted in prices increasing, with the average price for the second half 2009 to early 2012, fluctuating from US\$14 to US\$18/lb. Since then, prices have eased to below US\$13/lb in mid 2012.

Ivanhoe Australia Ltd's (Ivanhoe) **Merlin** molybdenum-rhenium (Re) deposit, approximately 100 kilometres (km) south of Cloncurry in northwest Qld has progressed through scoping, pre-feasibility and feasibility studies. Outcomes from the feasibility study, which was completed in April 2012, included a mine life of 15 years with a throughput rate of 500 kt a year (with a processing plant located at the nearby Osborne Mine), and an average production of 5100 tonnes of molybdenum and 7300 kilograms of rhenium a year for the first seven years. The feasibility study was based on an April 2012 upgrade of Probable Reserves to 7.1 million tonnes (Mt) at 1.1% Mo and 18.1 grams per tonne (g/t) Re for a contained 78 kt Mo and 129 tonnes Re. Indicated Resources are 6.7 Mt at 1.39% Mo and 23.4 g/t Re with contained 93 kt Mo and 157 tonnes of Re. Probable Reserves are included in the Indicated Resources.

The Merlin deposit consists of high-grade molybdenite mineralisation within the faulted basal metasediments of the Kuridala Formation in the Mount Isa eastern succession. The molybdenum mineralisation is overlain by discrete copper- and zinc-rich polymetallic sulphide zones of the Mount Dore ore body. The Merlin deposit is the world's highest grade molybdenum and rhenium deposit with very high-grade molybdenum mineralisation close to the surface at its southern end in the **Little Wizard** deposit. The company reported an Indicated Resource for Little Wizard of 15 000 tonnes grading 6.49% Mo, 83.9 parts-per-million (ppm) Re, 2.3% copper (Cu) and 25 g/t silver (Ag). Ivanhoe commenced construction of a decline at Merlin in late 2010 and reported that phase 1 was completed in early 2012. In late 2011, a cross-cut off the decline provided access to the Little Wizard ore body. Phase 2 of the decline development is awaiting project approval. Ivanhoe has been investigating strategic partnership options to secure long-term funding needed to progress development of Merlin and its other projects in the Cloncurry area.

Syndicated Metals Limited (Syndicated) announced a new farm-in and joint venture agreement with Cerro Resources NL in May 2011, giving Syndicated a controlling interest and management of the **Kalman** molybdenum-rhenium-copper-gold (Au) project, with rights to earn an 80% interest. The Kalman project is hosted by calc-silicate rocks of the Corella Formation within the eastern succession of the Mount Isa Inlier, around 60 km southeast of Mount Isa in northwest Qld. The deposit has Inferred Resources of 60.8 Mt at 0.05% Mo, 1.19 g/t Re, 0.32% Cu and 0.15 g/t Au, with a contained 30.4 kt of Mo. A total of 27.3 kt Mo occurs within an identified internal molybdenum domain of 24.9 Mt at 0.11% Mo and 2.78 g/t Re. Syndicated undertook drilling in late 2011 as part of a planned update of the Kalman resource model which will be used as a basis for an economic evaluation of the deposit.

Aeon Metals Limited (Aeon, formerly Aussie Q Resources Limited) continued exploration for porphyry copper-molybdenum mineralisation in its Rawbelle tenements near Monto, Qld. Focus was on both the advanced **Greater Whitewash Project**, comprising the **Whitewash, Gordon's, Whitewash South** and **Windmill Hill** molybdenum-copper deposits, and their copper-molybdenum exploration projects **John Hill** and **Kiwi Carpet**. The deposits of the Greater Whitewash Project occur within a 5 km corridor along strike of each other. The deposits have a total JORC Code compliant resource of 242 Mt grading 258 ppm Mo, 1173 ppm Cu and 1.54 ppm Ag, including Indicated Resources of 185 Mt grading 263 ppm Mo, 1189 ppm Cu and 1.55 ppm Ag with a contained 48.5 kt Mo. Mineralisation in these deposits occurs as veins within a molybdenum-copper porphyry system confined within

granodiorite. In October 2011, Aeon lodged a Mineral Development Licence for the Greater Whitewash Project, which it expects to be granted in the second half of 2012. The company have undertaken favourable metallurgical testing with good recoveries of molybdenum, copper and silver. The John Hill and Kiwi Carpet copper-molybdenum targets are approximately 10 km along strike from the Greater Whitewash Project. Aeon is continuing drilling at the John Hill Project, with indications it has identified a large porphyry system with potential ore grade mineralisation over wide intervals. Best drill intercepts include 494 metres (m) at 0.22% Cu, 163 ppm Mo and 1.09 ppm Ag and 128 m at 0.21% Cu, 71 ppm Mo and 0.9 ppm Ag. Best molybdenum intercepts included 5 m at 580 ppm and 25 m at 315 ppm Mo.

Aeon also has been drilling at the **Kildare Project**, 13 km south of the Greater Whitewash Project, which is owned by joint venture company SLW Queensland Pty Ltd (Aeon 35%, and Hong Kong based SLW Minerals 65%). Best drill results to date include 6 m at 4264 ppm Mo and 40 m at 475 ppm Mo.

In February 2011, Zamia Metals Limited reported an upgraded JORC Code compliant Inferred Resource of 173 Mt grading 0.43% Mo at a cut-off grade of 200 ppm Mo, for 163 million pounds of contained Mo, for its **Anthony** molybdenum deposit, approximately 60 km north-northwest of Clermont, Qld. The deposit is a porphyry molybdenum system associated with the Dead Horse Bore intrusive complex in which the molybdenite occurs in stockwork quartz veins and breccia zones within intrusive rocks as well as in surrounding schists of the Anakie Inlier. The deposit is oxidised to a depth of 60 to 80 metres. In June 2011 and March 2012, the Inferred Resources were upgraded to include the Oxide Resource and the Transitional Resource respectively, with total resources of 260 Mt at 400 ppm Mo, at a cut-off grade of 200 ppm Mo, for 230 million pounds of contained Mo. Zamia is evaluating project economics and joint venture options for the Anthony deposit.

Intermin Resources Limited's (Intermin) wholly owned **Julia Creek** Vanadium-Molybdenum project has a total resource of 5308 Mt grading 0.375% vanadium oxide (V_2O_5) and 312 g/t molybdenum trioxide (MoO_3), within the **St Elmo**, **Alisona** and **Lilyvale** deposits, spread between Julia Creek and Richmond, in northwest Qld. Just over 80% or 4332 Mt of the total resource comprises Indicated Resources with contained molybdenum of slightly more than 900 kt. The resource includes Measured Resources of 204 Mt at 0.4% V_2O_5 and 300 g/t MoO_3 . Intermin's tenements are located within the Cretaceous Toolebuc Formation of the Eromanga Basin, where vanadium and molybdenum, as well as nickel and copper, occur within weathered and fresh oil shale horizons. The company is undertaking laboratory testing and feasibility work into mining the Lilyvale resource, which includes higher grade Indicated Resources of 87.7 Mt at 0.55% V_2O_5 and 384 g/t MoO_3 . Intermin also is in negotiations with potential investors. The company has indicated that the moratorium on oil shale mining introduced by the previous Queensland government has complicated this task.

In 2011, Metallic Minerals Limited completed the sale of its wholly owned subsidiary, Wolfram Camp Mining Pty Ltd, to the German mining company Deutsche Rohstoff AG (DRAG) to give DRAG an 85% stake in the **Wolfram Camp** tungsten-molybdenum project, 90 km west of Cairns in Qld. In November 2011, DRAG announced it had acquired full ownership of Tropical Metals Pty Ltd which had held the remaining 15% of the Wolfram Camp Mine project, as well as all of the **Bamford Hill** tungsten-molybdenum deposit 25 km south of Wolfram Camp. This gave DRAG full control over both deposits. The most up-to-date resource estimate for Wolfram Camp was released by Planet Metals Limited in May 2010 and reported 1.42 Mt grading 0.6% tungsten trioxide (WO_3) and 0.12% Mo, comprising 0.78 Mt at 0.56% WO_3 and 0.13% Mo in Indicated Resources and 0.64 Mt at 0.65% WO_3 and 0.11% Mo in Inferred Resources. DRAG delivered its first WO_3 concentrate from Wolfram Camp in February 2012 and in June 2012 daily production was reported to be about 1.5 tonnes of concentrates a day. DRAG has forecast that the Wolfram Camp mine will produce approximately 7000 tonnes of WO_3 concentrates and 800 tonnes of Mo concentrates during the next four years. The company also announced a planned exploration program at both Wolfram Camp and Bamford Hill and indicated it was targeting a JORC Code compliant resource estimate for Bamford Hill.

Thor Mining PLC (Thor) has reported in January 2012 that its **Molyhil** tungsten-molybdenum project 250 km northeast of Alice Springs in the NT had Indicated Resources of 3.8 Mt at 0.29% WO_3 and 0.22% molybdenum disulphide (MoS_2) and Inferred Resources of 0.9 Mt at 0.25% WO_3 and 0.25% MoS_2 . Resource figures include Probable Reserves in open cut at April 2012 of 1.64 Mt at 0.42% WO_3 and 0.13% MoS_2 . Potential development of the project was hampered by the global financial crisis and a decline in international metal prices, resulting in the company scaling back activities. Thor had signed an off-take agreement with one of China's largest State-owned companies, CITIC Australia Trading Limited, committing it to taking all the molybdenum and tungsten concentrates produced from the project but that agreement has since lapsed. The recent increase in tungsten prices has resulted in renewed interest and in mid 2012 Thor completed a positive definitive feasibility study of the deposit, with a mine life of four years based on current reserves.

Moly Mines Limited's (Moly Mines) Spinifex Ridge Molybdenum-Copper Project, containing the **Spinifex Ridge** deposit is located in the Pilbara region about 50 km northeast of Marble Bar. The Spinifex Ridge deposit has a Measured and Indicated Resource of 206.8 million tonnes (Mt) at 0.06% Mo, 0.1% Cu and 1.5 g/t Ag and 445.5 Mt at 0.04% Mo, 0.07% Cu and 1.1 g/t Ag, respectively (2008 figures, reissued in 2012). The total resource of 652 Mt contains 294.5 kt Mo, 5.2 kt Cu and 26.4 million ounces Ag. Mineralisation at Spinifex Ridge occurs as vein-hosted molybdenite and chalcopyrite associated with an Archean granodiorite which has intruded mafic and felsic volcanic rocks. The Spinifex Ridge Molybdenum-Copper Project has all the necessary permits and is ready for immediate development. The deposit underwent a feasibility study and, prior to the global financial crisis, was scheduled to become Australia's only molybdenum producer. As indicated by Moly Mines, the deposit is sub-economic at current metal prices and is on hold until markets improve. Prior to the downgrade by Moly Mines, which resulted in reclassification of 220 kt of reserves to Paramarginal, the deposit contained more than 75% of Australia's EDR of molybdenum, but less than 1% of Australia's EDR of copper.

Peel Exploration Ltd (Peel) released a resource estimate in April 2008 of 1.29 Mt at 0.61% WO₃ and 0.05% Mo, for the **Attunga** deposit 20 km north of Tamworth in New South Wales (NSW). Mineralisation at the deposit occurs within skarns developed at the contact of a lime-rich sequence with the Inlet Monzonite. In 2010-11, Peel undertook a study to investigate development options, which revealed conditions were favourable for a low capital expenditure operation. There was no field activity in 2011-12. In April 2012, Peel indicated it had begun a review of the Attunga tungsten deposit. The company has indicated it is seeking potential joint venture/off-take partners.

In March 2012, Straits Resources Limited (Straits) announced a significant resource upgrade for its Temora copper-gold project southeast of West Wyalong in southern NSW. Total resources are 279 Mt at 0.5% Cu, 0.2 g/t Au, and 30 g/t Mo, of which 26 Mt at 0.3% Cu, 0.5 g/t Au and 30 g/t Mo are Indicated Resources with the remainder being Inferred Resources. The resource occurs within the **Yiddah**, Mandamah, Culingera, Estoril and Dam prospects.

In 2011, Zodiac Resources Pty Ltd which is 58.7% owned by Goodrich Resources, entered a farm-in agreement with Augur Resources (Augur), which allowed Zodiac to acquire a 75% interest in Augur's **Yeoval** Project, about 85 km north of Orange in NSW. Augur previously released an Inferred JORC Code resource estimate for the Yeoval Porphyry deposit of 12.9 Mt at 0.38% Cu, 0.14 g/t Au, 120.1 g/t Mo, and 2.2 g/t Ag. Zodiac completed an Induced Polarisation survey around the Yeoval deposit and its environs in 2012 which suggested that the known mineralisation was part of a larger mineralised system.

Dart Mining NL (Dart) released upgraded figures in September 2012 for its **Unicorn** Project 20 km south of Corryong in northeast Victoria which show the deposit has total resource of 203 Mt at 355 ppm Mo, 480 ppm Cu and 2.97 ppm Ag. These include Measured Resources of 102 Mt at 367 ppm Mo, 599 ppm Cu and 3.58 ppm Ag for a contained 38 kt Mo, and Indicated Resources of 35 Mt at 362 ppm Mo, 414 ppm Cu and 2.75 ppm Ag for a contained 13 kt Mo. Molybdenite (MoS₂) mineralisation at Unicorn is associated with rhyolitic intrusives and occurs within stockwork veins in the rhyolites, surrounding metasediments and breccia zones. It is disseminated also throughout the rhyolites. Dart completed a favourable scoping study into the deposit in October 2012, which suggested an initial open pit mine life of 14 years with annual production of 10 million tonnes per annum. Metallurgical testing demonstrated molybdenum recoveries of more than 90%. Dart has indicated it plans to initiate a prefeasibility study as well as look at the potential of underground mining.

Havilah Resources NL (Havilah) reported a combined JORC Code compliant Indicated and Inferred Resource of 11.3 Mt grading 0.89% Cu, 0.64 g/t Au and 500 ppm Mo for 5.68 kt of contained Mo for its wholly owned North Portia deposit 30 km north of its Kalkaroo deposit in South Australia. The vein and breccia style of mineralisation at the North Portia deposit is hosted in a 150-metre sequence of carbonate-rich siltstones and shales. Resources occur in both supergene and sulphide mineralisation. Havilah also identified a standalone supergene molybdenum resource with Indicated Resources of 7.7 Mt at 340 ppm Mo for a contained 2.6 kt of Mo. Havilah indicate that a mining lease has been granted for North Portia and that metallurgy and mining studies are in progress, particularly with regards to the copper-gold-molybdenum in the oxidised ore.

Nickel

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More than 80% of nickel production is used in alloys. When alloyed with other elements, nickel imparts toughness, strength, resistance to corrosion and various electrical, magnetic and heat resistant properties. About 65% of world nickel output is consumed in the manufacture of stainless steel, which is used widely in the chemical industry, motor vehicles, the construction industry and in consumer products such as sinks, cooking utensils, cutlery and white-goods.

Resources

Australia's Economic Demonstrated Resources (EDR) of nickel decreased by 13.8% from 24.0 million tonnes (Mt) to 20.4 Mt in 2011 as a result of mining companies updating their resources. About 87% of Australia's EDR is in 15 deposits. Australia's EDR of nickel can be subdivided as follows:

- About 34.5% of Australia's EDR comprise Reserves as defined under the Joint Ore Reserve Committee (JORC) Code.
- About 26.8% is made up of published JORC Code compliant Measured and Indicated Resources in operating mines, in deposits being developed for mining and in deposits which have published scoping/feasibility studies with positive results.
- The remaining 38.7% of Australia's EDR are in deposits with Measured and Indicated Resources of similar tonnage, grade and ore type which are being mined elsewhere in Australia, but have not completed a scoping/feasibility study.

Western Australia (WA) retains the largest nickel resources with 90.7% of total Australian EDR. New South Wales (NSW) is the second largest with 4.9%, followed by Queensland (Qld) with 4.4% and Tasmania (Tas) with 0.1%. The EDR in WA comprises both sulphide and lateritic deposits, while EDR in NSW and Qld are associated with laterite deposits.

Subeconomic Demonstrated Resources account for about 9.5% of total Identified Resources in 2012. At the same time, Paramarginal Resources increased from 2.4 Mt to 3.5 Mt, while the Submarginal Resources decreased from 1.3 Mt to 0.6 Mt. A total of 69.3% of the subeconomic nickel resources are in WA.

Inferred Resources decreased from 19.4 Mt to 18.4 Mt in 2011 with WA maintaining its dominance with 91.2% of the total followed by NSW with 3.4%.

The ratio of Inferred Resources to EDR in 2011 was 0.9:1.

Accessible EDR

Currently, all nickel EDR is accessible for mining. At the rate of production in 2011, Accessible Economic Demonstrated Resources (AEDR) of nickel is sufficient for about 95 years.

JORC Reserves

About 35% of AEDR is made up of Joint Ore Reserve Committee (JORC) Code Reserve. The remaining 65% of EDR represents resources assessed by Geoscience Australia from the Measured and Indicated categories of industry reported mineral resources as defined under the JORC Code and other classification systems used by companies not listed on the Australian Stock Exchange.

Total JORC Code Reserves of nickel are adequate for 33 years at current rates of production.

Exploration

Expenditure on nickel-cobalt exploration for 2011 as reported by the Australian Bureau of Statistics was \$262.1 million, an increase of 11.2% on 2010. WA attracted most of this expenditure with \$252 million.

Production

All of Australia's nickel production in 2011 was from WA and amounted to 215 kilotonnes (kt), up from 170 kt in 2010, as reported by the Australian Bureau of Resources and Energy Economics (BREE). The value of all nickel products exported was \$4.097 billion and was Australia's ninth most valuable mineral export commodity. Australia was the world's fourth-largest nickel producer behind Russia, Indonesia and Philippines accounting for 11.8% of estimated world mine production.

World Ranking

Based on figures published by the United States Geological Survey and the latest Australian resource figures, world economic resources of nickel increased to 76 Mt in 2011 from 75.6 Mt in 2010. Australia's share of world economic resources of nickel was 26.8% in 2011. It remained the largest holder of economic resources followed by New Caledonia (15.8%), Brazil (11.4%), Russia (7.9%) and Cuba (7.2%).

Russia was the largest producer with 280 kt (15.4%), followed by Indonesia and Philippines each with 230 kt (12.7%) and Australia with 215 kt (11.8%).

Industry Developments

In its Resources and Energy Quarterly 2012, BREE reported the average price for nickel in 2011 was about US\$22 854 per tonne, an increase from about US\$21 800 in 2010. In its 2012 annual report, BHP Billiton Resources Ltd noted again that the Chinese market has become a significant source of global demand for commodities. In the 2011 calendar year, China represented 61% of global seaborne iron ore demand, 39% of copper demand, 40% of nickel demand, 43% of aluminium demand, 48% of energy coal demand and 10% of oil demand. China's requirement for these commodities has been driving global materials demand for the past decade.

The major sulphide nickel mines, which are owned by BHP Billiton's Nickel West, continued operating at **Leinster**, **Mount Keith** and **Cliffs** north of Kalgoorlie in WA. Smaller sulphide nickel mines in WA continued to be operated by Mincor Resources NL, Panoramic Resources Ltd, Western Areas NL and Independence Gold NL. Xstrata Nickel Australasia Pty Ltd closed down its sulphide nickel operations at **Cosmos** in 2012 but continued its small nickel mine at **Sinclair**, WA. Minara Resources NL's **Murrin Murrin** lateritic nickel mine continued to operate in 2011 and First Quantum Minerals Australia Nickel Pty Ltd began production of nickel from its lateritic nickel operation at **Ravensthorpe** in October 2011.

Nickel sulphide deposits

BHP Billiton reported that its WA operations produced 109 000 tonnes of nickel during 2011 with most sourced from the Mount Keith, Leinster and Cliffs mines. Production was down from 123 800 tonnes in 2010 because of restrictions in hydrogen supply at Nickel West's Kwinana refinery, which is resulting in an increasing proportion of nickel matte being exported to overseas customers.

Most of the nickel ore treated at the Kambalda, Leinster and Mount Keith concentrators is smelted at the Kalgoorlie nickel smelter into nickel matte containing about 67% nickel. The mill and concentrator at Kambalda are supplied with third party ore and produce concentrate containing about 14% nickel. About 43% of the nickel matte was sold to overseas customers during 2009-10 compared with 60% in 2010-11. The nickel matte not sold overseas was refined at BHP Billiton's Kwinana nickel refinery to produce London Metal Exchange (LME) accredited nickel briquettes, nickel powder and other intermediate products such as cobalt-nickel-sulphide. The Kwinana nickel refinery has a capacity of 65 000 tonnes per annum (tpa) of nickel metal. BHP Billiton reported that a new hydrogen plant at its Kwinana refinery was successfully commissioned in the first half of 2012.

OJSC MMC Norilsk owns the Lake Johnston operations 500 kilometres (km) east of Perth, WA, and includes the **Maggie Hays** mine which re-opened in 2011. Norilsk noted in its annual report for 2011 and in its production report for 2011 that re-launch work at its pit and concentrator at the Lake Johnston project was completed and the concentrator was started in normal mode and its designed capacity was achieved in the second half of 2011. The ore for the concentrator is sourced from the Maggie Hays mine and the total nickel production in 2011 amounted to 1748 tonnes. The company investigated options for adapting existing nickel processing facilities at Cawse for the use of new hydrometallurgical technology.

The plant was expected to be re-oriented towards the processing of sulphide feedstock from Norilsk's Australian sulphide nickel deposits. Norilsk is planning to produce a nickel hydroxide with a nickel content of about 50%, which bypasses smelting by directly refining the semi-product. The use of this technology is expected to reduce the costs of refined metal.

Xstrata Nickel Australasia Pty Ltd operates the Cosmos nickel project in WA which is made up of a concentrator at Cosmos and mines at **Tapinos** and **Prospero**. Another operation, the Sinclair Mine, which has its own concentrator, is about 100 km southeast of the Cosmos operations. In September, Xstrata announced the suspension of operations at Cosmos project and introduction of a care and maintenance schedule in response to adverse market conditions, including a prolonged period of low nickel prices and a strong Australian dollar. Evaluation of the newly-discovered **Odysseus**, **Odysseus North** and **Odysseus Massive** deposits at Cosmos was continued, with a view to completing a feasibility study by the first quarter of 2014 to enable an investment decision, which would depend on market conditions. Despite the situation at Cosmos, operations at Sinclair continued at normal capacity.

Xstrata reported that the impact of mining more disseminated ore bodies with inherent lower nickel grades was offset by substantially increasing the amount of ore treated by 46% to 778 073 tonnes.

Xstrata announced that metal in concentrates produced in 2011 from the Cosmos and Sinclair operations, amounted to 17 034 tonnes of nickel, 881 tonnes of copper and 396 tonnes of cobalt²³. Additional information in the company's Preliminary Results 2011 noted that of the nickel produced, about 11 000 tonnes was from the Cosmos operation and about 6000 tonnes came from the Sinclair mine. The concentrate is transported by truck to the coastal town of Esperance in southwest WA and shipped to the Xstrata nickel smelter in Sudbury, Ontario.

Western Areas NL nickel mine at the **Flying Fox** deposit in WA produced 17 546 tonnes of nickel in concentrate in 2011. Open cut mining at the company's **Spotted Quoll** deposit produced 14 448 tonnes of nickel and an additional 197 tonnes of nickel in concentrates was produced from the underground ore drive at Spotted Quoll. All ore mined at Spotted Quoll is treated at the Cosmic Boy concentrator, which was upgraded during the first half of 2010 to a capacity of 550 000 tpa. The Cosmic Boy concentrator also treated the ore from the **Lounge Lizard** deposit. In March 2012, Kagara Ltd announced that it had completed the sale of its Lounge Lizard deposit to Western Areas. The nickel concentrate from the Cosmic Boy plant is delivered under off-take contracts to BHP Billiton in Kalgoorlie and to the Jinchuan Group in China.

During 2011, Panoramic Resources Ltd's underground mine operation at **Savannah** in WA produced 8343 tonnes of nickel, 4534 tonnes of copper, and 453 tonnes of cobalt. Nickel concentrates produced at the Savannah plant are contracted for sale to the Jinchuan Group in China. Panoramic continued to explore for extensions of the Savannah deposit below the 900 metre (m) structure and on 17 September 2012 reported drill intersections in two holes of:

- 9.7 m at 2.55% Ni, 0.52% Cu and 0.16% Co, and
- 8.5 m at 2.2% Ni, 0.51% Cu and 0.12% Co.

In 2011, **Lanfranchi** (WA) produced 10 205 tonnes of nickel and 903 tonnes of copper. On 12 April 2012, the company reported that drilling from the new hanging wall drill drive, testing the down-plunge extension of the Lanfranchi orebody, intersected broad zones of strong matrix and massive sulphide mineralisation including best intersections in three holes of:

- 13.66 m at 9.31% Ni,
- 12.59 m at 7.6% Ni, and
- 9.32 m at 6.3% Ni.

The ore from the Lanfranchi operation is processed at the Kambalda nickel concentrator owned by BHP Billiton.

Mincor Resources NL nickel production for 2011 was reported under two groups of operations in WA. They are the North Kambalda operation made up of the **Otter Juan** and **McMahon** and Mincor's 70% interest in the **Carnilya Hill** mine. The operations yielded a combined production in 2011 of 3812 tonnes of nickel, 241 tonnes of copper and 47 tonnes of cobalt. The Southern Kambalda operations produced 4979 tonnes of nickel, 481 tonnes of copper and 90 tonnes of cobalt, from the **Mariners** and **Mittel** operations. The Carnilya Hill mine was closed in March 2012. The ore body was discovered by Mincor in 2006 and mining commenced in early 2008. A total of 339 849 tonnes of ore at 3.18% Ni was produced, at a life-of-mine cash cost of \$4.96 per pound payable nickel.

23 Xstrata plc, 2012. Production report 2011. 11 pp.

Independence Group NL reported total production for 2011 of 9001 tonnes of nickel and 687 tonnes of copper from its **McLeay, Victor South, Moran and Long** mines in WA.

Fox Resources Ltd continued metallurgical testing for a possible bacterial heap leaching operation to treat nickel and copper resources from the **Radio Hill** mine and the nearby **Sholl** deposit in WA. The bacterial culture used to leach the metals from the sulphide ore is a mixed bacterial culture indigenous to the Radio Hill site. In mid-2010, the company announced updated Indicated and Inferred Resources of 4.22 Mt at 0.65% Ni and 0.76% Cu for its Radio Hill mine. An Indicated and Inferred Resource of 5.78 Mt at 0.54% Ni and 0.67% Cu was also reported for the **Sholl B2** deposit. In September 2011²⁴, Fox Resources released a preliminary scoping study, revised from March 2011 for its heap leaching project. The heap leaching operation is expected to have a net present value of \$73 million (8% discount rate) and an internal rate of return of 31% over the nine year life of the mine. The project is estimated to produce a net operating cash flow of \$125 million with project revenues of \$815 million over the initial mine life. In early 2012, Fox completed two drill holes adjacent to the existing trial pit at Radio Hill. The intersections are as follows:

- Hole 11RHDD123 - 1.0 m at 0.41% Cu and 0.29% Ni from 31.6 m;
- Hole 11RHDD123 - 0.95 m at 0.41% Cu from 47.05 m;
- Hole 11RHDD123 - 2.3 m at 0.40% Cu and 0.67% Ni from 49.2 m; and
- Hole 12RHDD124 - 8.9 m at 0.63% Cu and 0.38% Ni from 83.1 m, including 4 m at 0.82% Cu and 0.48% Ni.

The results will be used in a re-assessment of the near surface mineral resource and mining inventory for the Radio Hill heap leach project.

Poseidon Nickel Ltd announced on 12 November 2012 that the WA Minister for State Development had given conditional approval to resume nickel mining at the **Mount Windarra** site in the north eastern goldfields of WA. The proposal for the resumption of mining and processing operations at the Mount Windarra site includes:

- Resumption of nickel mining at the Mount Windarra underground mine;
- Commencement of nickel mining at the new **Cerberus** ore body;
- Construction of a nickel flotation concentrator plant capable of minimum throughput of 700 000 tpa;
- Construction of a gold tailings re-treatment facility; and
- Installation of in-pit tailings deposition via a slurry pipeline to South Windarra.

Sirius Resources NL announced that on 21 July 2012 it had discovered the **Nova** nickel-copper-cobalt deposit in the Fraser Range, WA. The discovery followed drilling the southern end of a 1.2-kilometre long electromagnetic conductor. By September 2012, Sirius had drilled approximately 70 holes over the southern half of this conductor and delineated thick, continuous mineralisation over an area measuring approximately 500 m down plunge and up to 400 m down dip. The mineralisation forms a thick lenticular slab which is up to 60 m thick in the central part. Some of the better intersections (all true width) are:

- Hole SFRD0061 - 61.68 m at 3.4% Ni, 1.27% Cu and 0.1% Co from 361.82 m, including 22.85 m at 5.83% Ni, 2.03% Cu and 0.17% Co,
- Hole SFRD0077 - 63.6 m at 3.41% Ni, 1.3% Cu and 0.11% Co from 349 m, including 15.23 m at 7.01% Ni, 2.36% Cu and 0.22% Co from 363 m, drilled approximately 50 m down dip from hole SFRD0061; and
- Hole SFRD0057 - 38.9 m at 3.23% Ni, 1.46% Cu and 0.1% Co from 393.01 m, including 24.86 m at 4.26% Ni, 1.77% Cu and 0.13% Co from 407.05 m, and including 10.11 m at 6% Ni, 2.75% Cu and 0.19% Co from 413.38 m, drilled towards the lower (eastern) edge of the deposit on the 700N line.

In addition, analyses of some drill samples have indicated platinum (Pt) values of 0.26 grams per tonne (g/t) and palladium (Pd) of 0.12 g/t.

Lateritic nickel deposits

The annual production for 2011 from the Murrin Murrin lateritic nickel plant in WA operated by Minara Resources Ltd was 28 500 tonnes of nickel and 1900 tonnes of cobalt. Another 1500 tonnes of nickel and 200 tonnes of cobalt

²⁴ Fox Resources Ltd, 2011. Quarterly activities report for the period ending 30 September 2011. 18pp.

were produced from third party ores. During 2011, the operation of the plant was hampered by a series of electrical storms, heavy rain and flooding. In addition, failure of an acid plant heat exchanger resulted in production continuing at a reduced rate until the heat exchanger was replaced. Production improved in the second half of the year, reflecting improved plant availability and an increase in processed ore-grade following the ramp-up to full production from the Murrin Murrin East ore body. In October 2011, Minara Resources was taken over by Glencore Investment Pty Ltd and was removed from listings on the Australian Securities Exchange.

First Quantum Minerals Australia Nickel Pty Ltd acquired the Ravensthorpe lateritic nickel operation in WA from BHP Billiton in February 2010. In a media release on 3 November 2011, First Quantum reported that:

- The plant is performing well and ramping up as planned towards commercial operations before the end of 2011;
- First production of nickel contained in mixed hydroxide was achieved on 4 October 2011;
- Re-constructed plants consistently achieving design throughputs; and
- Both Atmospheric Leach and Pressure Acid Leach plants have been brought on line.

First Quantum Minerals is planning to produce 39 000 tpa of nickel metal for the first five years and 28 000 tpa for the remainder mine life of about 30 years.

The SCONI (previously NORNIC) project in Qld is owned by Metallica Minerals Ltd and includes five key nickel-cobalt laterite deposits at **Greenvale, Lucknow, Kokomo, Minnamoolka** and **Bell Creek**. There has been significant interest in the company's potential to become a scandium producer. On 16 October 2012 Metallica announced²⁵ that SCONI's combined resource base of Measured, Indicated and Inferred Resources for the southern deposits of Lucknow, Greenvale and Kokomo stood at 59.5 Mt at 0.51% Ni, 0.07% Co, 64 g/t scandium (Sc) using a 0.7% Ni equivalent cut-off grade (Ni equivalent is calculated using $Ni + 1.5Co + 0.01Sc$ when the resource was estimated in October 2012).

Metallica has entered into a Heads Of Agreement with Bloom Energy to supply up to 30 000 kilograms (kg) of scandium oxide (Sc_2O_3) per annum (based on production output and Bloom Energy's global usage) with provision to increase supply up to 60 000 kg scandium oxide per annum (at Bloom's election) over the term of the agreement. Metallica has also entered into a non-binding Memorandum Of Understanding (MOU) with KBM Affilips, Europe's leading producer of master alloys.

Under the MOU, KBM Affilips will assist Metallica with its ongoing feasibility studies and in developing relationships with key aerospace and component manufacturing companies in procuring funding for the development of the SCONI project and enter into commercial negotiations with respect to an offtake agreement governing the sale of scandium from the SCONI project. Based on ongoing discussions with potential scandium oxide end users, Metallica has revised its potential estimates for future scandium oxide demand from SCONI. Metallica announced an updated mine plan and a scoping study, for the SCONI project to allow production of approximately 90 tonnes of scandium oxide per annum over not less than 20 years based on a processing rate of 750 000 tpa of ore. The revised mining plan, which is designed to increase the scandium oxide production level, results in an increased pre-tax net present value of \$870 million for the SCONI project (up from \$402 million) and increased average annual operating margin of \$213 million (up from \$179 million).

Metals X Ltd owns the **Wingellina** lateritic nickel deposit in WA which has a published Probable Reserve of 167.47 Mt at 0.98% Ni and 0.08% Co as published on 6 September 2012²⁶. In July 2010, Metals X signed a Mining Agreement with the Ngaanyatjarra Land Council for the Wingellina project. The agreement is subject to regulatory approvals and a mining lease being granted. It is also awaiting completion of final water and environmental studies as well as the majority of its technical studies²⁷. On 20 April 2011, Metals X through its wholly owned subsidiaries Austral Nickel Pty Ltd and Hinckley Range Pty Ltd entered into a Heads of Agreement with China's largest nickel producer, Jinchuan Group Ltd (Jinchuan) to sell to Jinchuan a 20% direct interest in the company's globally significant Wingellina Nickel-Cobalt Project as part of the project's advancement toward future production. In 2012, Metals X signed a non-binding MOU with Samsung C&T Corporation which is to complete an updated bankable feasibility study, provide technical expertise in engineering and assist with the financing and development proposals for the project.

25 Metallica Minerals Ltd, 2012. Announcement to the Australian Securities Exchange, 16 October 2012. 4pp.

26 Westgold Resources Ltd and Metals X Ltd, 2012. Announcement to the Australian Securities Exchange 6 September, 2012.

27 Metals X Ltd, 2011. Annual Report 2011. 126 pp.

The **Barnes Hill** project in Tasmania is a joint venture between Metals Finance, Proto Resources and Investments Ltd which owns the tenements. The project is based on a lateritic nickel deposit located in northeast Tasmania and has an Indicated Resource of 5.674 Mt of ore grading at 0.82% Ni and 0.06% Co. The Indicated Resource includes a Probable Reserve of 3.956 Mt at 0.84% Ni and 0.06% Co. In addition, the Barnes Hill deposit has an Inferred Resource of 933 000 tonnes at 0.77% Ni and 0.059% Co. Metals Finance has the right to earn a 50% equity interest in the project through the completion of flow-sheet designs, engineering and feasibility studies, procuring the funding required for implementation of the project and bringing it into production. A definitive feasibility study was completed at the end of June 2012. Proto also appointed Caterpillar Inc. as the equipment supplier to Barnes Hill and concluded a financing arrangement with Caterpillar Financial in Zurich. Proto is currently investigating the proposed processing route at Barnes Hill and expects to produce saleable iron and magnesium products as well as nickel and cobalt. An updated definitive feasibility study incorporated an increase in the throughput for the Barnes Hill project, from 250 000 tpa to 500 000 tpa²⁸.

The combined Measured, Indicated and Inferred Resources for GME's NiWest nickel laterite project comprising the **Mount Kilkenny, Hepi, Waite Kauri, Murrin North, Mertondale, Wanbana, Macey Hill** and **Eucalyptus** nickel-cobalt laterite deposits at a cut-off grade of 0.8% Ni amount to 75.73 Mt at 1.01% Ni and 0.06% Co. The deposits are located about 50 km east of the Leonora township in WA and is adjacent to Glencore's Murrin Murrin lateritic nickel-cobalt mine. The area is well serviced with infrastructure, including a gas pipeline, an open access rail line linked directly to ports and a sealed road running through the project area and linked to established mining townships on either side. Over the past five years GME has invested over \$15 million defining JORC Code compliant resources, undertaken metallurgical test programs, established water resources and completed pre-feasibility studies and partial feasibility studies on the development of a nickel heap leach operation²⁹.

The previous partner (Vale Inco) in Heron Resources Ltd's **Kalgoorlie Nickel Project (KNP)** in WA withdrew from the project in July 2009 after spending \$34.5 million on feasibility studies. Vale Inco completed a pre-feasibility study on four lateritic nickel deposits of the KNP project and Heron released a summary of the results in February 2009. That summary stated that the study investigated a project sized for up to 36 000 tpa of nickel intermediate product with a mine life of 34 years. A high-pressure acid leach operation was considered to be the best leaching technology with nickel and cobalt extractions of 96% nickel and 93% cobalt. Cash operating cost was estimated to be US\$4.42 a pound of nickel (including cobalt credits) and the capital cost was estimated to be US\$1.5 billion. Heron Resources completed further metallurgical studies and a detailed mining study that considered optimising individual pits and the sequence for mining. This study evaluated the project performance over three production rate scenarios of 2.5 Mt (Vale Base Case), 3.75 Mt and 5 Mt a year of leach feed. The company announced on 7 July 2011 that it had entered into a collaborative research agreement with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to undertake a detailed mineralogical and metallurgical study of the ore types at the KNP.

28 Proto Resources and Investments Ltd, 2012. Annual report 2012. 109pp.

29 GME Resources Ltd, 2012. Annual report 2012, 70pp.

Niobium

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Niobium (Nb) and tantalum often are found together in the same ores, namely columbite ((Fe,Mn)Nb₂O₆) and tantalite ((Fe,Mn)Ta₂O₆), as a result of their very similar chemical properties. Niobium is used with iron and other elements in stainless steel alloys. Niobium-titanium alloy wire is used in the medical sector for magnetic resonance imaging. Niobium alloys are strong and are often used in pipeline construction. The metal is used in superalloys for jet engines and heat resistant equipment. At cryogenic temperatures (minus 150 °C), niobium is a superconductor.

For location of niobium deposits refer to Fig. 14 in the Tin chapter.

Resources

Australia's Economic Demonstrated Resources (EDR) of niobium increased by 53% in 2011 to 205 kilotonnes (kt), up from 134 kt in 2010. The bulk of the EDR of niobium is associated with the Toongi deposit, 20 kilometres (km) south of Dubbo in New South Wales (NSW). This deposit is a sub-volcanic intrusive trachyte body (vertical) with dimensions of approximately 900 by 600 metres (m) which has been drilled out to a depth of 55 m to provide a Measured Resource of 35.7 million tonnes (Mt) grading 0.46% Nb₂O₅, and between 55 and 100 m for an Inferred Resource of 37.5 Mt grading 0.46% Nb₂O₅.

The other source of niobium EDR is the Brockman-Hastings deposit located 18 km southeast of Halls Creek in Western Australia (WA). This deposit, owned by Augustus Minerals Limited, is hosted by a fine-grained volcanoclastic unit informally known as the Niobium Tuff within a sequence of thick volcano-sedimentary rocks. The Niobium Tuff can be traced over a strike length of 3.5 km and varies in width up to 35 m. The deposit has a Joint Ore Reserve Committee (JORC) Code compliant resource of 36.2 Mt (grading 0.89% ZrO₂, 0.36% Nb₂O₅, 0.018% Ta₂O₅) comprising an Indicated Resource of 27.1 Mt grading 0.36% Nb₂O₅ and an Inferred Resource of 9.1 Mt grading 0.36% Nb₂O₅. These resources are based on a 1500 parts per million (ppm) Nb₂O₅ cut-off grade.

Paramarginal Resources totalling 82 kt (15 kt in 2010) account for all the Subeconomic Demonstrated Resources. They occur in the Brockman-Hastings (67 kt) in the Halls Creek Orogen and in the Mount Weld (15 kt) deposit in the eastern goldfields in WA.

No changes in the Inferred Resources (418 kt) have been recorded. Western Australia is the largest holder of Inferred Resources with 70% associated with the Mount Weld and the Brockman-Hastings Rare Metal deposits while NSW holds the remaining 30% in the Toongi deposit.

Accessible EDR

All of Australia's EDR of niobium is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total niobium in Proved and Probable Ore Reserves as defined in the JORC Code. In 2011, reserves of 115kt niobium have been reported. All are contained in the **Toongi** deposit.

Exploration

Exploration for niobium is occurring in WA and NSW, but there are no statistics available on exploration expenditure. Drilling by Alkane Resources Ltd at the Railway prospect within Dubbo Zirconia Project has intersected extensive zirconium, niobium, yttrium and rare-earth-element mineralisation. During 2011, Hastings completed a 51-hole drilling program at the Brockman-Hastings deposit and reported numerous significant intersections of ZrO₂, niobium and rare-earth elements.

Production

Currently there is no production of niobium in Australia. However, in previous years niobium concentrates were recovered as a by-product of tantalum mining.

World Ranking

Based on incomplete world estimates published by the United States Geological Survey (USGS) for 2011, the largest holders of the world's niobium resources are Brazil with 2900 kt and Canada with 200 kt. USGS data also estimates that world production of niobium in 2011 was 63 kt, which was a slight increase on 2010 production of 62.9 kt, and was dominated by Brazil with 58 kt and Canada with 4.4 kt.

Industry Developments

Historically, Global Advanced Metals (GAM) Pty Ltd (formerly Talison Minerals) **Greenbushes** mine in WA produced tantalite-columbite concentrate for export. Columbite $\text{Fe}(\text{Nb,Ta})_2\text{O}_6$ is the main niobium ore mineral. The company's primary tantalum plant at Greenbushes has been under care and maintenance since 2008, while its secondary processing plant treats primary tantalum concentrates from the **Wodgina** mine in the Pilbara region of WA. In January 2011, GAM announced the reopening of operations at the Greenbushes and Wodgina mines.

Galaxy Resources Limited (Galaxy) commenced production from its **Mount Cattlin** lithium-tantalum mine in December quarter 2010. In December 2010, GAM agreed to purchase 200 000 pounds (about 90 700 kilograms) of contained tantalum pentoxide over the next five years from the Galaxy Resources Mount Cattlin operation. GAM plans to upgrade this material for sale at its Greenbushes operations. When in full production, Galaxy expects to produce 137 000 tonnes per annum (tpa) of spodumene ($\text{LiAl}(\text{SiO}_3)_2$) and 56 000 tpa of tantalite contained concentrate, essentially as a by-product.

Alkane Resources Ltd is in advanced process of developing a Memorandum of Understanding (MOU) with a niobium consumer to form a Joint Venture to produce ferro-niobium from niobium concentrate for specialised alloy markets from the Dubbo Zirconia Project based on the Toongi deposit. In May 2011, the company signed an MOU with a large chemical company to produce around 15 to 20 kt a year of zirconium oxychloride, also using ore from the Toongi deposit.

Phosphate

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Phosphate rock is a general term referring to rock with high concentrations of phosphate minerals. It is the major resource mined to produce chemical fertilisers for the agriculture sector and 90% of phosphate rock goes towards this purpose. Plants require three major nutrients for life – nitrogen (N), potassium (K) and phosphorous (P). Phosphorous is used in the control of energy transfer and storage at the cellular level as well as playing an important role in metabolic processes.

Phosphorous is also used in animal feed supplements, food preservatives, in baking flour, pharmaceuticals, anti-corrosion agents, cosmetics, fungicides, insecticides, detergents, ceramics, water treatment and metallurgy.

There is no substitute for phosphate in agriculture.

The most common source of phosphate rock is phosphorite, which is a marine sedimentary deposit. The other source is guano, which is the accumulation of bird or bat excrement. The most common phosphate minerals belong to the apatite group, $\text{Ca}_5(\text{F,Cl,OH})(\text{PO}_4)_3$, with main minerals being collophane, francolite and dahlite.

Australia's commercial resources of phosphate are in northwest Queensland (Qld) at Phosphate Hill, 140 km southeast of Mount Isa and on the remote offshore territory of Christmas Island in the Indian Ocean. Phosphate Hill is a world-class rock phosphate resource that is close to the surface and easy to access and mine. The rock is ideal for the manufacture of high analysis mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) fertilisers for domestic and international use.

Christmas Island is a source of quality rock phosphate which is exported to the Asia-Pacific region with products used widely as direct application fertiliser in the palm oil sector of the region. Higher-grade rock phosphate is used by Australian manufacturers of MAP fertiliser.

DAP and MAP fertilisers have different ratios of phosphorous and nitrogen, and have slightly different applications. Both products are generally produced as granules with a diameter of between 2-4 mm. DAP (20% P and 18% N) is used for broad-acre products such as cereal, legume, fodder and horticultural crops as well as for dairy and newly established pastures. MAP (22% P and 10% N) assists with early crop growth and enhances phosphorous uptake in broad-acre crops. Ideally, phosphate rock for fertiliser production will contain approximately 30% phosphorus pentoxide (P_2O_5), around 5% calcium carbonate and less than 4% iron and aluminium oxides.

Resources

Australia's total Economic Demonstrated Resources (EDR) of phosphate rock in 2011 was 945.4 million tonnes (Mt), compared with 492.1 Mt in 2010. Upgrades at Paradise South (QLD), Wonarah (NT) and Mt Weld (WA) account for the bulk of the increase.

Australia has a total demonstrated resource of 1390 Mt, of which 445 Mt (32%) is classified as paramarginal. All of the phosphate occurrences in Queensland and the Northern Territory occur as phosphorites in the Georgina Basin, which hosts 89% of Australia's demonstrated resources. The remaining 11% occurs at Christmas Island and in Western Australia within carbonatite at Mount Weld and at the Balla Balla magnetite deposit.

About 1646 Mt (90%) of Australia's Inferred phosphate Resources, which total 1813 Mt, also occurs in the Georgina Basin. The remainder occurs in WA, mostly at the Mount Weld deposit but small amounts (less than 5 Mt) occur also at Balla Balla and Cummins Range.

Australia's EDR of phosphate occur at:

- Phosphate Hill (Qld) – average grade 23.9% P_2O_5 ,
- Paradise South (Qld) – average grade 11.0% P_2O_5 ,
- Paradise North (QLD) – average grade 28.4% P_2O_5 ,
- Wonarah (NT) – average grade 18.2% P_2O_5 ,
- Nolans Bore (NT) – average grade 13.5% P_2O_5 ,
- Ammarroo (NT) – average grade 16.4% P_2O_5 ,
- Mt Weld (WA) – average grade 14.3 % P_2O_5 , and
- Christmas Island – figures not publically available.

Published grades for EDR range from 8.7% P₂O₅ at Paradise South to 28.4% P₂O₅ at Paradise North. Traditionally, phosphate rock needs to have an average grade of around 30% P₂O₅ for direct shipping. However, as high-grade resources are declining and demand is projected to increase, companies are increasingly evaluating projects in which lower grade phosphate resources will be mined and then beneficiated through processes such as washing, flotation and calcining. Similarly, milling operations in which phosphate products are produced as a by- or co-product are potentially economic at low grades.

Phosphate prices, as sourced from the World Bank, are expressed in the amount of US\$ paid per metric tonne for free-alongside-ship (f.a.s.) Moroccan phosphate (70% bone phosphate of lime (BPL)). Figure 10 shows the monthly price chart for phosphate since 2008 when phosphate prices were at their peak before crashing during the global financial crisis. By 2011, prices had recovered from the lows of US\$90 that occurred in 2009. Prices for 2011 steadily climbed from US\$155 in January to US\$202 in December. They fell in 2012, dipping to US\$175 in May and June and recovered by December 2012 to US\$185.

The long-term annual price chart for phosphate rock (Figure 11) shows that, for the most part, phosphate prices are generally flat but subject to price spikes from time to time. The price spike in 1974-75 was caused by the Moroccan Office Cherifien des Phosphates radically increasing the price for phosphate, followed quickly by Nauru and American producers. Phosphate demand, however, slumped and prices gradually returned to the long-term average. The price spike in 2007-8 was a result of two economic factors combined with an already overheated market: The first was real increased fertiliser demand for food in developing regions (particularly Asia) and, importantly, for the emerging biofuel industry. The second factor was the resulting speculation about this increased demand and its implications for food security. The fact that prices have not yet returned to the long-term real dollar trend is possibly a truer reflection of the increased demand for fertilisers in Asia and other developing regions.

Accessible EDR

Virtually all of Australia's Economically Demonstrated Resources of phosphate are accessible. A small resource on Christmas Island is inaccessible because of environmental restrictions.

JORC Reserves

In 2011, Joint Ore Reserve Committee (JORC) Code Reserves in the Proved and Probable Reserve categories comprised 280 million tonnes of phosphate accounting for approximately 30% of accessible EDR with the remainder defined as Measured and Indicated Resources.

Exploration

Data on exploration expenditure for phosphate are not available in published statistics. However, exploration for phosphate remained active across Western Australia, Queensland and the Northern Territory, buoyed by steady prices and the predicted increase in world demand for fertilisers.

Over 2011 and 2012, Rum Jungle Resources Ltd completed 2082 RC holes for 61 221 m, along with 32 diamond drill holes, at the Ammaroo Phosphate Project in the Northern Territory. Results include 8 m at 30.8% P₂O₅ from a depth of 15 m, 9 m at 26.6% P₂O₅ from a depth of 8 m, and 8 m at 35.1% P₂O₅ from a depth of 36 m.

Other large exploration programs were carried out at the Korella deposit at Corella Bore (Qld) by Krucible Metals Limited with 47 RC percussion holes for 2107 m exploring for phosphate and rare earths and at Cummin Range (WA) where Kimberley Rare Earths Limited completed a 77-hole, 4230 m RC drilling program. Rox Resources Limited completed a 29-hole, 1900 m RC drilling program at Marqua (NT) in 2011, which included results of 4 m at 26.3% P₂O₅ from 45 m, 5 m at 20.7% P₂O₅ from 25 m and 7 m at 20.2% P₂O₅ from 12 m.

A smaller drilling program was instigated by Minemakers Limited in 2012 to test the general potential of its western, southwestern and northwestern tenements at their Wonarah Project in the Northern Territory.

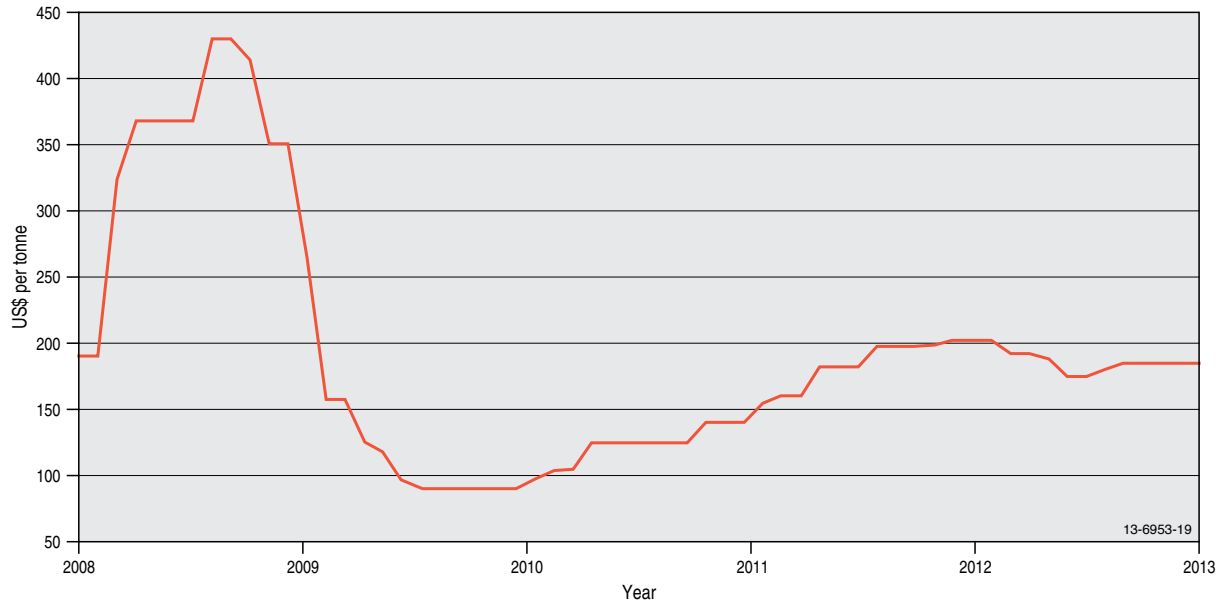


Figure 10. Monthly phosphate prices since 2008 for phosphate rock (Morocco), 70% BPL, contract, f.a.s. Casablanca. Source: World Bank.

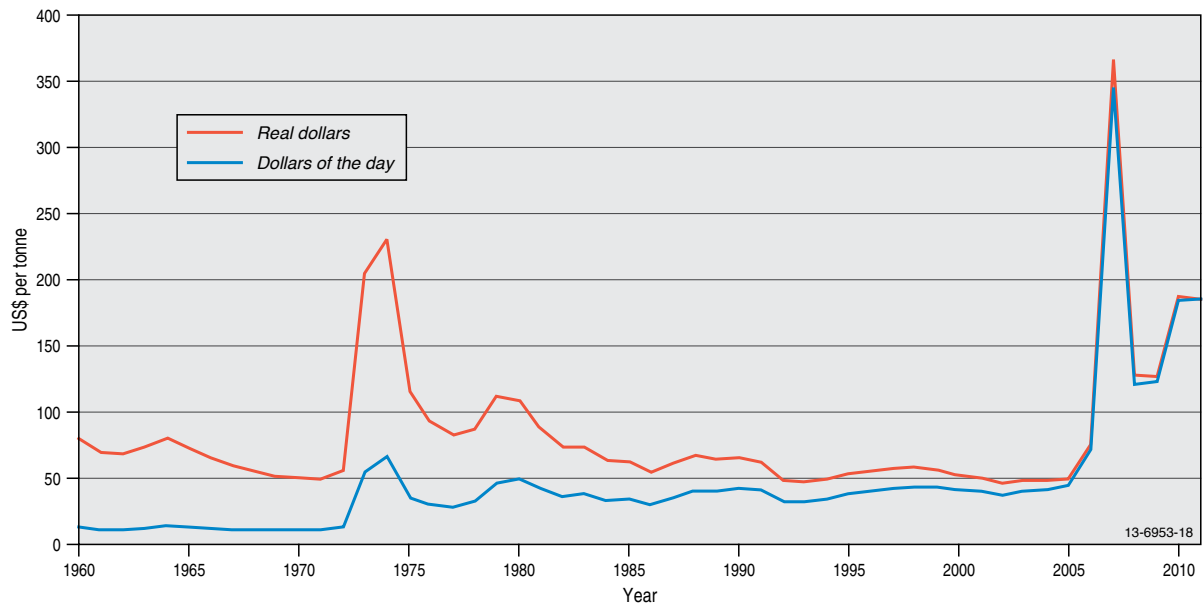


Figure 11. Long-term phosphate prices since 1960 for phosphate rock (Morocco), 70% BPL, contract, f.a.s. Casablanca. Source: World Bank.

Production

There are two main locations for the production of phosphate rock in Australia: Phosphate Hill in Queensland and Christmas Island in the Indian Ocean. In 2011, Incitec Pivot Limited produced 2.49 Mt of phosphate rock from Phosphate Hill and Phosphate Resources Limited produced 604 569 tonnes of phosphate rock and 62 410 tonnes of phosphate dust from Christmas Island.

Several small operations near Bendleby in South Australia (SA) produced about 1650 tonnes of phosphate rock in 2011 (2547 tonnes in 2010), which is used mainly in domestic industrial applications.

World Ranking

The United States Geological Survey (USGS) estimates that total world resources of phosphate rock are 71 000 Mt. Australia's EDR comprises less than 1% of the world's resources. Morocco and Western Sahara jointly hold about 70%, followed by Iraq with 8%, China with 5% and Algeria with 3%. Syria, South Africa, Jordan and United States of America each hold around 2% of the world's phosphate resources.

The USGS estimated that world production of phosphate rock in 2011 totalled 191 Mt (181 Mt in 2010), with China producing 72 Mt, the USA 28.4 Mt, Morocco and Western Sahara 27 Mt and Russia 11 Mt.

Industry Developments

Christmas Island: Phosphate Resources Limited produced 604 569 tonnes of phosphate rock and 62 410 tonnes of phosphate dust in 2011. Figures from the previous year are not available but in 2009 the company produced 420 205 tonnes of phosphate rock and 42 300 tonnes of phosphate dust. Current resources are expected to last another five years but the company is actively exploring and seeking additional land for mining. In 2012, Phosphate Resources applied to the Commonwealth for the resumption of the land it gave up for the proposed, but now withdrawn, Asia Pacific Space Centre.

Phosphate Hill (Qld): Incitec Pivot Limited, a publically listed company on the Australian Stock Exchange, does not to publish resource figures. The last publically available JORC compliant resource for Phosphate Hill dates from BHP Billiton's Annual Report 2006 and quotes a Proven Reserve of 29 Mt at 24.6% P_2O_5 and a Probable Reserve of 52 Mt at 24.3% P_2O_5 .

Incitec Pivot continues to work the Phosphate Hill deposit, mining some 2.49 Mt in 2011. The phosphate rock feeds into the Phosphate Hill fertiliser plant, the company's largest, which has a current (reduced) annual capacity of 900 000 tonnes. The plant's capacity is reduced owing to production problems at the company's Mt Isa sulphuric acid plant. The sulphuric acid is used at Phosphate Hill, along with ammonia, to produce ammonium phosphates. Incitec Pivot also produces superphosphates at its Geelong and Portland plants.

Corella Bore (Qld): Krucible Metals Limited is developing its Korella phosphate and rare earths (yttrium) project at the Corella Bore prospect immediately south of Phosphate Hill. The yttrium at the Korella deposit is contained in the phosphate mineral xenotime (YPO_4). In June 2012, the company received an Environmental Authority for level 1 mining activity on the lease. In August 2012, Krucible Metals was granted the Korella Phosphate Mining Lease for a quarry-style trial mining operation of the phosphate ore. The company will now progress to a feasibility study and bulk sample preparation. Also in August 2012, Krucible Metals signed a Heads of Agreement with Getax International, a Singaporean company, with a view to forming a Joint Venture for mining and trading the phosphate from the Korella project. Current resources at the Korella prospect are reported as an Inferred Resource of 8.3 Mt at 27.3% P_2O_5 and 13.72 Mt at 0.70 kg/t Y_2O_3 .

Paradise South and Paradise North (Qld): The Paradise North and Paradise South deposits (formerly known as Lady Jane and Lady Annie, respectively) are located some 70 km north of Mount Isa and owned by Paradise Phosphate Limited, a wholly owned subsidiary of US company Legend International Holding Inc. The company's primary aim is to develop the Paradise North prospect for mining and producing phosphate for direct shipping ore (DSO). The project has an Indicated Resource of 3.3 Mt at 28.4% P_2O_5 and an Inferred Resource of 4.0 Mt at 27.9% P_2O_5 . A mining lease was granted in April 2011 for the production of up to 1 Mt per annum of phosphate rock.

In addition, the company received approval in July 2012 for its Environmental Impact Statement from the Department of Environment and Heritage Protection for an open-cut mining operation at Paradise South. The mine is expected to produce up to 7 Mt per annum of phosphate rock over 20 years. Paradise South has a Proven and Probable Reserve of 198.6 Mt at 12.7% P_2O_5 , which will be beneficiated on site to a saleable product of 52.7 Mt at 32.1% P_2O_5 .

The company has also proposed a fertiliser plant at Mount Isa and has engaged specialist consultants to prepare detailed plans and environmental studies.

The proposed Initial Public Offering (IPO) of Paradise Phosphate Limited on the Australian Stock Exchange was withdrawn by parent company Legend International Holdings Inc in October 2012. Legend International Holdings cited the reason that advanced negotiations with a strategic partner were nearing fruition and that it was better to achieve this goal prior to an IPO.

Highland Plains (QLD, NT): The Queensland portion of the Highland Plains phosphate deposit is owned by Legend International Holdings Inc and was included in the withdrawn float of Paradise Phosphate on the Australian Stock Exchange. To date, there has been no further drilling at this part of the prospect and resources remain at a historical, non-JORC estimation of 84 Mt at 13.4% P₂O₅.

The Northern Territory portion of the Highland Plains phosphate deposit is owned by Phosphate Australia Limited. In 2009, the company released a maiden Inferred Resource of 56 Mt at 16% P₂O₅. In 2011 and 2012, the company has been investigating the potential for beneficiating the resource through froth flotation to a grade of around 34% P₂O₅ and transporting the slurry by pipeline to a barging facility in the Gulf of Carpentaria. The company also owns the geologically along-strike Alexandria, Alloy and Buchanan Dam prospects (some 130-170 km distant from Highland Plains) from which historical phosphate occurrences have been recorded.

Wonarah (NT): Minemakers Limited released an updated resource estimate for the Wonarah phosphate deposit in October 2012 as part of a feasibility study. The company claims it is Australia's largest undeveloped rock phosphate project. It has a Measured and Indicated Resource of 300 Mt at 18.3% P₂O₅ and an Inferred Resource of 542 Mt at 18% P₂O₅. Earlier, in June 2012, a non-binding Memorandum of Understanding (MoU) that the company had entered into with the National Mineral Development Corporation Limited, one of India's largest mining companies, expired. The company is now seeking other partners to bring the project to fruition.

Nolans Bore (NT): Arafura Resources Limited announced a 52% increase to the tonnage of its mineral resources at Nolans Bore in March 2012 and slightly improved it again in June 2012 to the current total resource estimate of 47 Mt at 2.6% REO, 11% P₂O₅ and 0.41 lb/t U₃O₈. In December 2012, the company defined its JORC compliant Probable Reserve as being 24 Mt at 2.8% REO, 12% P₂O₅ and 0.45 lb/t U₃O₈.

The company is projecting a mine life of 22 years based on open pit mining methods and beneficiation. It plans to transport the mineral concentrate to its proposed Rare Earths Processing Complex which will be located in Whyalla, South Australia. There, it will separate the concentrate into two streams – one for rare earths and one for phosphate. Final products will comprise rare earth oxides, a solid phosphate product, gypsum and uranium oxide.

Other activities during 2011 and 2012 have included fundraising and deal making with a number of international companies. Arafura Resources is now working towards a final feasibility study.

Ammaroo/Barrow Creek (NT): In December 2011, Rum Jungle Resources Ltd released a resource upgrade for the Barrow Creek 1 prospect at its Ammaroo Phosphate Project in the Northern Territory. The deposit has an Indicated Resource of 13 Mt at 16.4% P₂O₅ and an Inferred Resource of 240 Mt at 15% P₂O₅. Work in 2012 has included further extensive drilling at both the Barrow Creek 1 and Ammaroo deposits, as well as bench-scale metallurgical testing for beneficiation. The company plans to mine the high-grade portion of the Barrow Creek 1 deposit for direct shipping and is currently bulk-sample testing for this. The lower grade portion of the Barrow Creek 1 deposit will be beneficiated through screening, desliming (removing clay particles) and flotation.

Arganara (NT): In 2011, NuPower Resources Limited announced the results of a rock chip sampling program that returned results up to 37.6% P₂O₅ and began a RC drilling campaign in September 2011. In August 2012, the company released a maiden Inferred Resource of 310 Mt at 15% P₂O₅ (10% cutoff) and 15 ppm U. The estimates were based on XRF assays from 387 RC drill holes for 14 480 m of drilling. The company's current activities at Arganara are infill drilling targeting a DSO resource (>30% P₂O₅). At Lucy Creek, the company has also completed a soil sampling program in 2012 following a 2009 drilling campaign and has plans for further geochemical (soil survey) work at the Warrabri phosphate project in 2012/13.

Geolsec (NT): There have been no updates by Korab Resources Limited regarding their plans to commence development of a phosphate deposit located at GeolSec near Rum Jungle, 65 km south of Darwin. To date, subject to receiving all the necessary approvals, the company still plans to develop a simple quarrying operation with no processing other than grinding and bagging to supply the agricultural sector with a finely ground-up rock phosphate to be used for direct application as an organic fertiliser.

Mount Weld (WA): Mount Weld is one of the world's richest deposits of rare earth elements and continues to be developed by Lynas Corporation Limited. The deposit also contains a significant phosphate resource and, in March 2011, Lynas entered into an agreement with Forge Resources Limited to sublease designated areas of the orebody for the exploitation of niobium oxide at the Crown deposit and phosphate at the Swan deposit. The Swan deposit has

an Indicated and Inferred Resource of 77 Mt at 13.5% P₂O₅. However, in May 2011, the agreement was terminated by Lynas, citing shareholders' wishes that it focus its energy on the rare earths project.

Balla Balla (WA): The Balla Balla deposit is primarily a vanadium-titanium-magnetite project but also contains a phosphate resource of 89.7 Mt at 3.74% P₂O₅. During 2012, the Balla Balla project was purchased by Forge Resources from Atlas Iron limited with the view to developing the V-Ti-Fe project. The company has no current plans to exploit the phosphate resource but will be stockpiling the gabbro-host as they access the underlying titanomagnetite ore zone, with a view to the possibility of processing the phosphate-rich gabbro in the future.

Cummins Range (WA): In 2011, Kimberley Rare Earths Limited acquired 25% of the Cummins Range rare earth oxide-uranium-phosphate deposit, 130 km southwest of Halls Creek as part of a Joint Venture with Navigator Resources Limited. They completed a 77-hole RC drilling program for 4230 m but, in October 2012, they terminated the JV agreement and relinquished their interest in Cummins Range back to Navigator. In September 2012, Navigator Resources announced a 17% increase in the Inferred Resource for Cummins Range to 4.9 Mt at 11.2% P₂O₅, 145 ppm U₃O₈, 1.74% REO and 48 ppm Th. Navigator also completed a pit optimisation study and a conceptual mine schedule in order to develop a Preliminary Evaluation Study.

Platinum Group Elements

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The platinum group elements (PGE) comprise platinum (Pt), palladium (Pd), iridium (Ir), osmium (Os), rhodium (Rh) and ruthenium (Ru). The elements of most commercial significance are platinum, palladium and, to a lesser degree, rhodium. The PGE properties of commercial importance are their resistance to corrosion and oxidation, high-melting points, electrical conductivity and catalytic activity in the chemical, electrical, electronic, glass and motor vehicle industries. The emerging commercial importance of PGEs is in applications associated with the motor vehicle industry resulting from increasing global emission controls, development of lead-free petrol and efforts to improve fuel efficiency. Other applications include the use of platinum-rhodium alloys to oxidise ammonia to nitric acid in the production of fertilisers, while platinum is used extensively in jewellery.

According to figures published by Matthey (2012)³⁰, gross demand for platinum increased by 2% to just under 8.1 million ounces (Moz) in 2011, largely because of extensive acquisition by glass and petrochemical industries. The main demand for platinum in 2011 was for autocatalyst applications, which amounted to 3.11 Moz. The gross industrial demand for platinum reached 2.05 Moz, and demand for platinum in the jewellery section totalled 2.48 Moz. Gross demand for palladium increased by 23% to 9.63 Moz in 2011, its highest ever level. Gross demand for palladium from the autocatalyst sector in 2011 reached a record level of 6.03 Moz as a result of higher global production of vehicles and greater use of palladium in light duty diesel emissions control.

Resources

Australia's Economic Demonstrated Resources (EDR) of PGEs increased from 4.4 tonnes to 4.7 tonnes in 2011.

Western Australia (WA) and the Northern Territory (NT) hold all of Australia's EDR. However, the EDR of PGEs in individual deposits within State and Territory jurisdictions is often unrecorded resulting in the overall distribution of the PGE EDR being unknown.

In 2011, Paramarginal Resources increased from 132.6 tonnes to 135.3 tonnes while the Submarginal Resources remained the same at 35.3 tonnes. The Paramarginal Resources are shared mostly between WA (88.6%) and New South Wales (NSW) (11.2%), while most of the Submarginal Resources are in WA.

Inferred Resources increased by 2.7 tonnes to 148.2 tonnes with WA having most of these resources (87.5%) followed by NSW (10.1%).

Total Identified Resources of PGEs, which represents EDR plus Paramarginal, Submarginal and Inferred Resources, total about 323 tonnes. Of this amount, deposits that have only PGE resources account for about 60% of the total resources, although all of Australia's production is as a by-product from PGE resources associated with nickel sulphide deposits in WA.

Accessible EDR

Currently, 400 kilograms (kg) of the published PGE EDR is accessible for mining while the balance of 4.3 tonnes occurs within national parks. The reason for the low Accessible EDR figure for PGEs is that PGE resources are generally not reported by companies.

JORC Reserves

About 2.5% of Accessible Economic Demonstrated Resources (AEDR) of PGEs comprises Joint Ore Reserve Committee (JORC) Code reserve. The remaining 97.5% of EDR represents resources assessed by Geoscience Australia from the Measured and Indicated categories of industry-reported mineral resources, as defined under the JORC Code and other classification systems used by companies not listed on the Australian Stock Exchange. The reason for the low reserve figure is that many companies don't report the PGE content in nickel reserves.

³⁰ Matthey, J, 2012. Platinum 2012. Johnson Matthey Public Limited Company. Precious Metals Marketing. http://www.platinum.matthey.com/uploaded_files/PT_2012/platinum_2012_publication.pdf

Exploration

Expenditure for PGEs is not reported separately and much of the PGE resources are associated with nickel deposits. Areas of activity in 2011 where PGEs were a significant component of exploration targets included regions of the Yilgarn in WA's eastern goldfields, the East Kimberley and West Pilbara as well as the West Musgrave in the border region of WA, the NT and South Australia (SA).

Production

Australia's PGE production (platinum and palladium) in 2011 was very minor by world standards amounting to 441 kg. This production is exclusively from nickel sulphide deposits hosted by Archean komatiitic rocks in the Yilgarn Craton of WA.

World Ranking

Based on figures published by the United States Geological Survey and the latest Australian resource figures, world economic resources of PGEs was down from 71 000 tonnes in 2010 to 66 000 tonnes in 2011. Australia's share of world EDR was less than 0.1% in 2011. South Africa has most of the world's EDR with 63 000 tonnes (95%), followed by Russia with 1100 tonnes (1.7%) and the USA with 900 tonnes (1.4%).

The world's supply of PGEs in 2011 was dominated by South Africa (72% Pt, 38% Pd) and Russia (14% Pt, 41% Pd), with minor contributions from Canada, Zimbabwe, the USA and Colombia.

Industry Developments

Platinum Group Elements as the Major commodity

About two thirds of Australia's Identified Resources of PGEs are in the following deposits, which have PGEs as the major commodity.

Munni Munni (WA): Published Measured, Indicated and Inferred Resources of 23.6 million tonnes (Mt) at 1.5 grams per tonne (g/t) Pd, 1.1 g/t Pt, 0.1 g/t Rh, 0.2 g/t gold (Au), 0.09% nickel (Ni), and 0.15% copper (Cu). In its 2012 Annual Report, the owner of the deposit, Platina Resources Ltd, reported that the project was on hold.

Panton (WA): Measured, Indicated and Inferred Resources total 14.3 Mt at 2.19 g/t Pt, 2.39 g/t Pd, 0.31 g/t Au, 0.27% Ni, and 0.07% Cu. On 20 March 2012, Platinum Australia Ltd announced the results of a review of the Panton project, reporting that it would generate a net present value (NPV) on base case assumptions of US\$15 million with an initial capital cost of US\$172 million. The operating costs was estimated to be US\$830 an ounce of Pt+Pd+Au concentrate produced with an average annual production rate of 83 000 ounces. On 21 May 2012, Panoramic Resources Ltd announced that it had purchased the Panton PGE deposit from Platinum Australia Ltd.

Fifield (NSW): Platina Resources Ltd³¹ announced Indicated and Inferred Resources totalling 12.7 Mt at 0.7 g/t Pt for its Owendale North, Cincinnati and Milverton deposits at Fifield. The company also published a scandium (Sc) resource of 10.1 Mt at 340 g/t Sc. Historical production from Fifield amounts to about 640 kg of PGEs. On 11 September 2012³², Platina Resources announced results of a scoping study which indicated an economic and technical viability of a combined platinum and scandium mining operation supporting an average mining rate of 6.9 million tonnes per annum (Mtpa) for three years. After three years the scandium-bearing stockpile laterite will continue to be processed at a rate of:

- 0.9 tonnes of platinum being produced per annum for three years,
- 40 tonnes of scandium oxide produced per annum for 41 years.

For the scoping study, capital expenditure was estimated to be \$222 million, and annual operating costs of \$62 million for the first three years, reverting to approximately \$42 million once platinum processing ceases.

31 Platina Resources Ltd, 2012. Project update: Owendale platinum and scandium resource, NSW, Australia. Announcement to the Australian Securities Exchange, 26 April, 2012.12 pp.

32 Platina Resources Ltd, 2012. Platina Resources delivers positive scoping study for Owendale project. Announcement to the Australian Securities Exchange, 6pp.

Weld Range – Parks Reef (WA): A published Inferred Resource amounted to 14.76 Mt at 1.1 g/t Pt+Pd+Au which occurs in a truncated lateritic profile overlying low-grade primary PGE mineralisation in ultramafic rocks³³. The Weld Range PGE deposit is adjacent to the very large Weld Range lateritic nickel-cobalt deposit which has an Inferred Resource of 330 Mt at 0.75% Ni and 0.06% Co. An Inferred Resource of 63.5 Mt at 5.2% chromium (Cr), 38% iron (Fe) and 0.38% Ni at a cut-off grade of 4% Cr also occurs within the Weld Range nickel cobalt deposit. A scoping study was released by Weld Range Metals Ltd in August 2010 which concluded that Stage 1 of the project is technically and economically feasible using processing equipment and technology currently used by the steel industry. Dragon Mining noted in its 2012 Annual Report that on 21 September the National Native Title Tribunal determined that four mining licence applications over the Weld Range deposit should not be granted by the WA State government. The State government and the company have lodged appeals with the Federal Court with respect to the National Native Title Tribunal determination.

Platinum Group Elements as the Minor commodity

PGE resources are present also in deposits where other commodities are dominant, mainly komatiitic nickel-cobalt sulphide deposits as well as lateritic nickel deposits. They include the following deposits.

Rosie (WA): South Boulder Mines Ltd announced an updated total Indicated and Inferred Resource of 1.94 Mt at 1.7% Ni, 0.4% Cu, 0.8 g/t Pt and 1.1 g/t Pd³⁴.

Radio Hill nickel mine (WA): Fox Resources Ltd reported that remaining Indicated and Inferred Resources of palladium amounted to 1.275 Mt at 0.493 g/t. In mid 2010, the company announced updated Indicated and Inferred Resources of 4.22 Mt at 0.65% Ni and 0.76% Cu for its Radio Hill mine. An Indicated and Inferred Resource of 5.78 Mt at 0.54% Ni and 0.67% Cu was reported also for the nearby Sholl B2 deposit, but no details were given for palladium content. The mine is on care and maintenance while the company is investigating options for heap leaching nickel and copper. On 15 November 2011, the company announced it had signed a non-binding Memorandum of Understanding (MOU) with Jiangxi Jiangli Sci-Tech Co. Ltd regarding the development of the Radio Hill and Sholl nickel-copper bacterial heap leaching project in the Pilbara region of WA. Under the proposed agreement contemplated by the MOU, Jiangli, a Chinese cooperative, is to provide \$30 million to Fox for the initial phase of the project and other associated project activities required at Radio Hill Mine. As part of the agreement, Fox will provide Jiangli with all the nickel and copper sulphide concentrates produced from its Radio Hill and Sholl projects over their initial nine year mine life.

Waterloo nickel mine (WA): The resources for this deposit were reported last in 2004 as 653 000 tonnes at 2.795% Ni, 0.194% Cu and 0.858 g/t PGE. Recorded production amounts to 185 000 tonnes at 2.76% Ni in 2007 and 57 818 tonnes Ni in 2006 but there are no details on production of PGEs. The mine's owner, OJSC MMC Norilsk Nickel, placed the mine on care and maintenance in November 2008 because of prevailing low nickel prices and reduced world demand.

Nyngan lateritic nickel-cobalt-scandium-platinum deposit (NSW): Jervois Mining Limited reported in June 2005 a resource of 16 Mt at 0.87% Ni and 0.06% Co of which there is 3 Mt at 290 parts per million (ppm) Sc and 0.22 g/t Pt. The scandium-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718 Mt at 274 ppm Sc and Indicated Resources of 9.294 Mt at 258 ppm Sc.

The Horn nickel sulphide deposit (WA): In April 2008, Breakaway Resources Limited reported a small Inferred Resource for The Horn nickel deposit of 600 000 tonnes at 1.39% Ni, 0.3% Cu and 0.5 g/t Pd+Pt. In early 2009, the company reported that massive and matrix nickel sulphide mineralisation at The Horn deposit had been drilled over a 500 metre (m) strike length and remained open along strike. Geological mapping undertaken during the March quarter of 2009 confirmed the presence of nickeliferous gossans within a structurally bound, high magnesium oxide (MgO) ultramafic unit immediately south of the known mineralisation. The Revolution prospect³⁵, located immediately north of Breakaway's The Horn nickel deposit includes PGE-bearing disseminated nickel mineralisation (12 m at 0.96% Ni, 311 ppm Cu and 424 parts per billion (ppb) Pt+Pd from 192 m and 4 m at 1.14%Ni, 1003 ppm Cu and 749 ppb Pt+Pd from 209 m in drill hole LWDD0809).

33 Parks, J, 1998. Weld Range platinum group element deposit. In: *Geology of Australian and Papua New Guinean Mineral Deposits* (eds: Berkman, D.A. & Mackenzie, D.H.), The Australasian Institute of Mining and Metallurgy: Melbourne, 279–286.

34 South Boulder Mines Ltd, 2012. September Quarter operations report. 30pp.

35 Breakaway Resources Limited, 2011. Activity report for the quarter ended 31 December 2010. ASX Release 28 January 2011, 12 pp.

Yarawindah Brook (WA): An Inferred Resource of 2.9 Mt at 0.79 g/t PGE was announced by Washington Resources Ltd in March 2006. The deposit was acquired by Northern Minerals Ltd in 2010.

Bamboo Creek tailings (WA): Haoma Mining NL announced on 5 October 2012 that assay results of samples of trial concentrates produced from its recently designed Bamboo Creek pilot plant by the Elazac Process were suitable for commercial extraction of gold and PGEs (platinum and palladium). The company reported that commercial production was planned to commence in the near future.

Binti Gossan and Binti South (WA): Emu Nickel NL reported in its 2011 Annual Report that a drilling program at Binti Gossan and Binti South had intersected significant nickel, cobalt and PGE values with some of the best downhole intersections including 0.30 m at 7.55% Ni, 0.35% Co, 1015 ppb Pt and 1726 ppb Pd.

Jack's Hills (WA): Victory Mines Ltd reported on 12 November 2012³⁶ that gossan samples collected at the Jack's Hills prospect returned analytical results of up to 13.9% Cu, 87.1 ppm Ag, 0.77% Ni, 0.24 ppm Au, 1.12 ppm Pt and 1.20 ppm Pd. Historical drill hole samples from a drilling program in 2007 returned values of up to 3.7% Cu, 1.14 g/t Au, 0.48% Ni, 0.73 g/t Pt and 14.4 g/t Ag³⁷.

Other PGE deposits with recorded resources which have had historic interest but did not record exploration or assessment activity during 2011 include:

Nebo-Babel nickel-copper-PGE deposit (WA): An article in The West Australian newspaper, dated 10 February 2007, reported that the Nebo-Babel nickel-copper-PGE deposit discovered by Western Mining Corporation in mid-2000 has a preliminary resource of 393 Mt grading 0.3% Ni, 0.3% Cu and 0.18 g/t PGE. The deposit was later acquired by BHP Billiton Limited as a result of its takeover of Western Mining Corporation in mid-2005.

Syerston lateritic nickel-cobalt-platinum deposit (NSW): In April 2000, Black Range NL announced a total platinum resource of Measured, Indicated and Inferred Resources of 108.3 Mt at 0.21 g/t Pt which occurs partly within the Syerston nickel-cobalt deposit. In a preliminary prospectus, Ivanplats Limited announced on 10 September 2012 that an internal study in 2005 indicated that, because of increasing capital and operating costs, development of the Syerston deposit was not economically attractive. However, Ivanplats announced that it was monitoring technological advances which could make Syerston commercially viable.

Coronation Hill (NT): It was reported in 1990 that the Coronation Hill deposit had an Inferred Resource of 6.69 Mt at 6.42 g/t Au, 1.01 g/t Pd and 0.3 g/t Pt. The deposit occurs within the Kakadu National Park and is inaccessible for mining.

Adamsfield³⁸ (Tasmania): The deposit it is located 70 km west of Hobart within the Franklin-Gordon Wild Rivers National Park. A small near surface Inferred Resource amounts to 14 500 tonnes of ore at 6.5 g/t Ir, 7.3 g/t Os and 0.13 g/t Pt using a cut off grade of 1 g/t Os+Ir.

Thomson River (Victoria): In 1981, CRA Exploration Pty Ltd estimated resources as 40 000 tonnes averaging 3.2 g/t Pt, 3.6 g/t Pd, 2.7% Cu, 9.5 g/t Ag and 2.5 g/t Au. Intermittent mining since the discovery of the deposit in about 1864 produced around 13 200 tonnes of ore, from which only about 10 kg of platinum was extracted.

36 Victory Mines Ltd, 2012. Clara Hills rock chip sampling and RC drilling program completed. Announcement to the Australian Securities Exchange, 12 November 2012, 2pp.

37 Victory Mines Ltd, 2012. Prospectus, 144pp.

38 Shree Minerals Limited, 2009. Shree Minerals Limited Prospectus. 160 pp.

Potash

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The term potash refers to potassic fertilisers, which are potassium chloride (KCl or sylvite), potassium sulphate (K_2SO_4 or sulphate of potash (SOP), which is usually a manufactured product), and potassium-magnesium sulphate ($K_2SO_4 \cdot 2MgSO_4$ or either langbeinite or double sulphate of potash magnesia (SOPM or K-Mag)). Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride (halite) for fertiliser use, which includes minor amounts of other nontoxic minerals from the mined ore and is neither the crude ore sylvite nor pure sylvite.

Resources

Historically, Australia has always been deficient in known resources of potash but ongoing exploration has led to recent published resources for some deposits such as the Lake Disappointment, Lake Chandler and Dandaragan Trough/Dinner Hill deposits in Western Australia (WA), in the WA/Northern Territory (NT) portion of Lake MacKay, and in the Karinga Creek Salt Lakes area in southern NT.

JORC Reserves

Currently there are no Joint Ore Reserve Committee (JORC) Code reserves for potash resources.

Exploration

Interest in exploration for potash continued in 2011 in Lake Disappointment, Lake MacKay, south Carnarvon Basin, Perth Basin and Canning Basin in WA as well as the Adavale Basin in Queensland (Qld), in the Barrow Creek area in the NT and in Ceduna area in South Australia (SA).

Production

According to the United States Geological Survey (USGS), about 90% of the world potash production in 2010 was consumed by the fertiliser industry. Potassium chloride is the main fertiliser product, containing an average 61% of K_2O equivalent. In 2011, the main producers of potash were Canada with 11.2 million tonnes (Mt) followed by Russia (7.4 Mt) and Belarus (5.5 Mt). The three accounted for about 65% of the world production of 37 Mt, which was up from 33.7 Mt in 2010.

In Australia, some minor historic production of potash include an operation at Buladelah Mountain, New South Wales, where alunite $KAl_3(SO_4)_2(OH)_6$, was mined between 1890 and 1926 and again from 1935 to 1952, for a total production of 75 000 tonnes. Crude potash in form of the soluble salt glaserite ($K,Na)_2SO_4$, was produced from Lake Chandler (WA) during 1943 to 1950 for a total of 9218 tonnes.

In 1973, Geoscience Australia's predecessor, the Bureau of Mineral Resources, reported that Texada Mines Pty Ltd was working towards becoming Australia's first local potash producer in the form of langbeinite $K_2Mg_2(SO_4)_3$ at Lake Macleod in northwest WA. The planned capacity of the proposed plant was variously reported to be from 80 000 to 200 000 tonnes per annum (tpa). There is no record of production of potash from the proposed operation.

Australia imports all its potash requirements and according to the Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) Australian Commodity Statistics 2010, the imports of potassium fertiliser amounted to 210.6 kilotonne (kt) in 2007-08 and 339.8 kt in 2008-09.

World Ranking

According to the United States Geological Survey, the countries with the largest economic resources of potash (K_2O) in 2011 were Canada 4.4 gigatonnes (Gt), which represents about 46% of the total world resource, followed by Russia with 3.3 Gt (35%) and Belarus with 0.75 Gt (8%).

Industry Developments

Lake Disappointment (WA): Located in the Gibson Desert of WA about 320 kilometres (km) east of Newman, Lake Disappointment is a modern playa lake covering approximately 1600 square kilometres. Potash mineralisation occurs in lacustrine sediments of the lake and in the entrained brine.

On 13 March 2007, Reward Minerals Ltd published a lower estimate of 7705 Mt Indicated Resource at 3.17 kilograms per tonne (kg/t) K_2SO_4 containing 24 Mt K_2SO_4 and an upper estimate of 8635 Mt at 3.17 kg/t K_2SO_4 containing 27.37 Mt K_2SO_4 . The difference between the upper and lower figure is the result of assumptions about the depth and area for the lake margins. On 30 October 2012, Reward Minerals lodged the Lake Disappointment Project Mining and Indigenous Land Use Agreement with the Native Title Tribunal for registration as an indigenous land use agreement (ILUA) between the Martu representative body Western Desert Lands Aboriginal Corporation (Jamukurnu-Yapalikunu), Holocene Pty Ltd and Reward Minerals Ltd. Reward Minerals has been granted a Mining Lease and a Miscellaneous Licence and is seeking to advance the next phase of the Lake Disappointment project through exploration and feasibility stages.

Lake Chandler (WA): On 29 January 2009, ActivEX Limited announced a JORC Code compliant Inferred Resource of 5 779 025 tonnes at 5.73% K_2O at its Lake Chandler potash deposit 45 km north of Merredin and 300 km east of Perth in WA. The company stated in its 2010 annual report that it carried out a scoping study on a nominal throughput of 200 000 tpa to give the project a mine life of 25 years. The company concluded that the study showed that, with the softness of the potash market, the project would be only marginal under current economic conditions.

Lake MacKay (WA,NT): Situated in the Gibson Desert and straddling the WA/NT border 50 km north of the Tropic of Capricorn, Lake MacKay is a modern, playa lake with a surface area of more than 2250 square kilometres. Reward Minerals reported in its 2009 annual report that it has delineated a JORC Code compliant Inferred Resource at Lake MacKay of 4780.4 million bench cubic metres (BCM) at 4.3 kilograms (kg) of K_2SO_4 (SOP) per BCM for a total of 20.56 Mt of K_2SO_4 .

The resource estimate was calculated on the basis of lake bed sediment volume of BCM to a depth of two metres and the water soluble potassium sulphate content of the sediments that lie within the company's tenement holdings.

The company reported in its annual report for 2011 that the next stage of development at Lake MacKay will involve infill drilling, construction of pilot ponds and pump testing as well as flow sheet development for the preparation of a project feasibility study.

Prior to committing to this phase the company has engaged in discussions with the Tjambu Tjambu people and other traditional owner groups aimed at reaching agreement on terms that would be acceptable for development to proceed at Lake Mackay in the event feasibility analysis proved favourable³⁹.

Dandaragan Greensands Project (WA): Potash West NL is exploring the potential for producing potash from greensand deposits in the Perth Basin, located between 50 and 230 km north of Perth⁴⁰. The company is investigating the possibility of using conventional magnetic separation techniques to separate glauconite from greensands and is conducting laboratory-scale testing to produce marketable potash products from glauconite concentrate⁴¹. On 11 October 2012, Potash West announced an initial Indicated and Inferred Resource of 244 Mt at 3% K_2O and 1.6% P_2O_5 for the Dinner Hill deposit containing the Molecap Greensand and the Poison Hill Greensand stratigraphic greensand units. On 16 November 2012, the company reported that a scoping study for the project was planned to be completed by the end of 2012 and a bankable feasibility study was to be completed by the end of 2013.

Karinga Creek Project (NT): Rum Jungle Resources Ltd, in a joint venture with Reward Minerals Ltd, was analysing potassium, magnesium and sulphate levels in aquifers surrounding Karinga Creek Lakes, about 225 km southwest of Alice Springs in the NT⁴². On 5 November 2012, Rum Jungle Resources announced an Inferred Resource of 5.5 Mt of sulphate of potash (K_2SO_4) for the Karinga Creek potash deposit⁴³.

39 Reward Minerals Ltd, 2012. Reward Minerals Ltd annual report 2011. 64pp.

40 Potash West NL, 2010. Prospectus, 96 pp.

41 Potash West NL, 2012. Potash West succeeds in producing potash from WA glauconite deposits. Announcement to the Australian Securities Exchange, 23 January 2012, 3 pp.

42 Rum Jungle Resources Ltd, 2011. Karinga Creek potash update. Announcement to the Australian Securities Exchange 20 December, 2010. 6 pp.

43 Rum Jungle Resources Ltd, 2012. Upgraded Karinga Creek Potash brine resource estimate. 6pp.

Rare Earths

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The rare earth elements (REEs) are a group of 17 metals that comprise the lanthanide series of elements - lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu) - in addition to scandium (Sc) and yttrium (Y), which show similar physical and chemical properties to the lanthanides. The REEs have unique catalytic, metallurgical, nuclear, electrical, magnetic and luminescent properties. Their strategic importance is indicated by their use in emerging and diverse technologies that are becoming increasingly more significant in today's society. Applications range from routine (e.g., lighter flints, glass polishing mediums, car alternators) to high technology (lasers, magnets, batteries, fibre-optic telecommunication cables) and those with futuristic purposes (high-temperature superconductivity, safe storage and transport of hydrogen for a post-hydrocarbon economy, environmental global warming and energy efficiency issues). Over the past two decades, the global demand for REEs has increased significantly in line with their expansion into high-end technological, environmental and economical environments (Hoatson et al 2011⁴⁴).

During the past couple of years, Sc-bearing lateritic nickel-cobalt (Ni-Co) deposits have attracted increasing attention in response to anticipated rise in demand for Sc. Zirconia stabilised with Sc rather than Y as an electrolyte for Solid Oxide Fuel Cells (SOFCs) reduces the operating temperature of the fuel cell significantly, thereby providing a much longer life. SOFCs are expected to play a major role in the developing battery-powered, electric transportation industry (cars, trucks, trains, etc) as well as in stationary applications such as electricity generation in the home or as a substitute for coal-fired power plants⁴⁵.

The group of REEs is variously, and inconsistently, reported by companies as light REEs consisting of La, Ce, Pr, Nd and, sometimes, Sm. Heavy REEs may start with Sm, followed by Eu through to Lu. However, the heavy REEs are sometimes subdivided further into middle REEs comprising Sm, Eu, Gd, Tb and Dy with the remainder of the group, Ho to Lu, referred to as the heavy REEs. Because of inconsistent reporting, the component elements of light, medium and heavy REEs are best noted in each case. The resources of REEs are usually reported as rare earth oxides (REO). Kingsnorth⁴⁶ grouped La to Nd as light REEs, or Ceric, Sm to Gd as medium REEs and Tb to Lu plus Y as heavy REEs, or Yttric.

Table 11. Distribution of types of REEs in selected deposits (Arafura Resources Ltd).

Rare Earth Oxide	Application	Nolans Bore (%)	Mount Weld (%)	Mountain Pass USA (%)	Baiyunebo China (%)
Lanthanum	Petroleum cracking catalysts, batteries (NiMH)	19.74	25.6	33.2	27.1
Cerium	Autocatalyst, glass, polishing	47.53	45.74	49.1	49.86
Praseodymium	Magnets, glass	5.82	5.42	4.34	5.15
Neodymium	Magnets (NdFeB)	21.2	18.62	12.0	15.4
Samarium	Magnets, (SmCo)	2.37	2.44	0.8	1.15
Europium	Phosphors, nuclear control applications	0.4	0.55	0.12	0.19
Gadolinium	Intravenous contrast agents, phosphors	1.0	0.97	0.17	0.4
Terbium	Phosphors	0.08	0.09		
Dysprosium	Magnets (NdFeB), lasers	0.33	0.16		0.3
Other Rare Earths (Ho, Er, Tm, Yb, Lu)		0.21	0.04	0.16	0.03
Other elements					
Yttrium	Phosphors, metal alloys	1.32	0.37	0.1	0.2

44 Hoatson, D.M., Jaireth, S. and Miezitis, Y., 2011. The major rare-earth-element deposits of Australia: geological setting, exploration, and resources. Geoscience Australia, 204 pp.

45 EMC Metals Corporation of Canada in a press release on 8 February 2010 on the Toronto Stock Exchange.

46 Kingsnorth, K., 2010. The challenges of meeting 'Energy' rare earths demand. IEA Standing Committee on Long-Term Co-operation Paris, 17th May 2010.

The REEs are a relatively abundant group of elements that range in crustal abundance from Ce, which is the twenty-fifth most abundant element at 60 parts per million (ppm), to Lu, the sixty-first most abundant at 0.5ppm.

Table 12. Applications for REEs in the emerging technology areas.

Application	Rare Earth Elements
Light Weight Magnets	<p>Cars Light weight magnets in motors for windows, windscreen wipers, starter motors, alternators, etc</p> <p>Electronics Magnets in disc drives for computers, data storage, portable music players (eg iPods), video recorders, consoles, video cameras</p> <p>Speakers Wind turbine</p>
Catalyst	<p>Automotive catalyst Clean diesel Oil refining</p>
Hybrid vehicles	<p>Electric motors and generators Hybrid batteries</p>
Compact fluorescent lights, energy saving lamps	
Polishing powders	<p>TV and computer screens LCD, Plasma, CRT</p> <p>Optical lenses</p> <p>Precision optical and electronic components</p>
Glass additives	<p>CRT screens to stabilise glass from cathode ray</p> <p>Small optical lenses</p> <p>Phosphors TV and computer screens</p>
Ceramics	

Resources

Geoscience Australia's estimate of Australia's rare earths reported as REO on 31 December 2011, amounted to 2.03 million tonnes (Mt) of Economic Demonstrated Resources (EDR), 0.41 Mt Paramarginal and 34.48 Mt in the Submarginal Resource categories.

- About 31% of Australia's Accessible EDR comprises Reserves as defined under the Joint Ore Reserve Committee (JORC) Code.
- About 69% comprises published JORC Code compliant Measured and Indicated Resources in operating mines, deposits being developed for mining and in deposits which have published scoping/feasibility studies with positive results.

There is a further 25 Mt REO in the Inferred Resources category. About 53 Mt REO (predominantly La and Ce) of the Submarginal and Inferred Resources are in the Olympic Dam iron oxide-copper-gold deposit in South Australia (SA). The REO at Olympic Dam are not recovered in current mining operations and finish up in the tailings storage facility at the mine site. About 6190 tonnes of Sc, mostly in the Subeconomic and Inferred categories were reported in 2011. In addition, about 56 140 tonnes of Paramarginal and Inferred Resources were reported as REEs.

Significant resources of REEs are contained in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucosene and zircon content. Monazite is a rare earth-thorium-phosphate mineral found within heavy mineral sand deposits in Australia. Using available information, Geoscience Australia estimates Australia's monazite resources to be in the order of 7.4 Mt. Assuming the REO content of monazite to be about 60%, the heavy mineral deposits could hold a resource of around 4.44 Mt contained REO. Currently, extraction of REEs from monazite is not viable because of the cost involved in the disposal of thorium and uranium present in the monazite.

Table 13. Distribution of types of REEs in monazite from different parts of the world (modified after Mukherjee 2007⁴⁷).

REO	Guangdong China (weight%)	Taiwan (weight%)	Australia (weight%)	Florida, Usa (weight%)	India (weight%)
La ₂ O ₃	23	21	23.2	17.4	22
CeO ₂	42.7	47.9	46.3	43.7	46
Pr ₆ O ₁₁	4.1	5.4	4.9	4.9	5.5
Nd ₂ O ₃	17	18.7	18.3	17.1	20
Sm ₂ O ₃	3	3.3	2.5	4.9	2.5
Eu ₂ O ₃	<0.1	0.54	0.04	0.16	0.016
Gd ₂ O ₃	2	1.6	1.7	6.5	1.2
Tb ₄ O ₇	0.7	0.19	0.22	0.26	0.06
Dy ₂ O ₃	0.8	0.35	0.56	0.59	0.18
Ho ₂ O ₃	0.12	0.03	0.08	0.11	0.02
Er ₂ O ₃	<0.3	0.03	0.06	0.04	0.01
Tm ₂ O ₃	TR	-	-	0.03	Tr
Yb ₂ O ₃	0.24	0.07	0.04	0.21	Tr
Lu ₂ O ₃	<0.14	-	-	0.03	Tr
REO	55	48-62	58.5	-	58
Other elements					
Y ₂ O ₃	2.4	0.19	1.57	3.18	0.45
ThO ₂	4	0.41	6.4	-	9.5

Production

Historically, Australia has exported large quantities of monazite from heavy mineral sands mined in Western Australia (WA), New South Wales (NSW) and Queensland (Qld), for the extraction of both REEs and thorium. Between 1952 and 1995, Australia exported 265 kilotonnes (kt) of monazite with a real export value (2008 dollars) of \$284 million (Australian Bureau of Statistics 2009)⁴⁸.

Small-scale production of REEs has taken place in Australia but records on these activities are incomplete. The following information on historical attempts to establish a rare earth production industry in Australia is drawn from Cooper 1990⁴⁹. In the 1950s, Zircon Rutile Ltd at Byron Bay, NSW, processed a small quantity of monazite to produce cerium oxide for use in glass polishing. In 1969, Rare Earth Corporation of Australia Ltd, operating at Port Pirie, SA, began producing cerium, lanthanum, yttrium and thorium compounds from locally produced monazite. However, the plant ceased operations in mid 1972 because of a lack of working capital and the difficulty of breaking into world markets for processed rare earths.

In January 1987, it was announced that the French chemical company Rhone-Poulenc proposed to build a two-stage monazite processing plant at Pinjarra in WA to produce rare earths from monazite, but the project was suspended. Deckhand Pty Ltd, a wholly owned subsidiary of Currumbin Minerals, was blocked in 1988 on environmental grounds from establishing a rare earths processing plant at Lismore, NSW. SX Holdings Ltd of SA was planning to establish a plant at Port Pirie to process monazite with a 2000 tonnes per annum (tpa) cracking and separation plant but the project did not proceed.

47 Mukherjee, T.K., 2007. Thorium resources in India, its mining, separation and chemical processing. IAEA Technical meeting on 'Thorium based fuels and fuel cycle options for pressurized heavy water cooled reactors, light water reactors and high temperature gas-cooled reactors. 22 to 25 October, 2007. Istanbul, Turkey.

48 ABS, 2009. International trade, Cat. No.5465.0, Canberra.

49 Cooper W., 1990. Queensland mineral commodity report. Queensland Government Mining Journal, September 1990. Department of Resource Industries, 383-389.

Barrie (1965)⁵⁰ reported that a pegmatite deposit six kilometres (km) east of the Cooglegong crossing, WA, was worked in 1913 and 1930 and yielded about two tonnes of gadolinite (yttrium iron beryllium silicate (Ce,La,Nd,Y)₂FeBe₂Si₂O₁₀). An analysis of Cooglegong gadolinite yielded 45.78% of yttrium trioxide (Y₂O₃) and 4.81% of other REO. Note that gadolinite does not contain more than trace amounts of gadolinium.

In 2007, mining operations commenced at the Mount Weld deposit in WA and around 98 000 cubic metres of ore has been stockpiled pending the completion of a concentration plant at the mine site. There has been no recorded production of REO in Australia during the period 2007 to 2011.

Globally, the production and resources of rare earths are dominated by China followed by India. China accounts for about 94% of the production but this is expected to fall to 70% by 2015 (Roskill, 2012⁵¹) while India accounts for about 2%. These figures are only approximate because production for the Commonwealth of Independent States, which is made up of former members of the Soviet Union, is not available.

The main consumers of rare earths are China, the United States of America, Japan, Korea and Thailand with China reportedly accounting for about 70% of the world's consumption in 2011 (Roskill op. cit.).

According to Roskill (op. cit.), all the growth in demand between 2005 and 2010 of 11% per year was from China while growth in the rest of the world fell by almost 4% per year. The reduction was largely the result of the global economic downturn in 2009 and a tightening of the Chinese export quota in 2010, which restricted availability. In the years to 2015, the main demand driver will be the use of rare earths in neodymium-iron-boron (NdFeB) magnets, which are forecast to grow between 11 and 13% per year as potential markets expand to include applications in permanent magnet motors for electric vehicles and wind turbines. Magnets could account for nearly one third of demand by 2015. Strong growth in demand is forecast also for rare earths in nickel-metal hydride (NiMH) batteries, phosphors, optical glass and ceramics.

Lynas Corporation Limited reported in May 2011⁵², that demand for rare earths of 127 000 tonnes in 2010 is set to increase to about 177 200 tonnes in 2014.

China has continued a nationwide crackdown on the illegal mining of rare earths. In addition, it has been reported that on 6 August 2012 China's Ministry for Industry and Information Technology introduced new restrictions which are expected to reduce the existing 23 rare earth mines in China by one third and the 99 smelting and extracting operations by up to a half⁵³.

World Ranking

China holds 55 Mt (48.2%) of the world's economic reserves for REO, followed by the Commonwealth of Independent States with 19 Mt (16.7%) REO and the United States of America with 13 Mt (11.4%)⁵⁴. Australia's EDR accounts for 1.82% of world's economic reserves with 2.07 Mt REO.

The main types of REE deposits worldwide include the Bayan Obo deposit in China, which is predominantly REE-iron ores with bastnasite and monazite as the main REE bearing minerals. The only production of REOs from a carbonatite has been the Mountain Pass deposit in California, which has 35.35 Mt of Measured, Indicated and Inferred Resources at 6.35% REO (2.24 Mt REO). Deposits associated with carbonatite laterites, include Araxa in Brazil, which has 28.29 Mt of Measured, Indicated and Inferred Resources at 3.754% REO (1.06 Mt REO) and Mount Weld in WA, which has 23.94 Mt at 7.867% REO (1.88 Mt REO). Other deposit categories with significant REO resources include a vein type at Nolans Bore in the Northern Territory (NT) and an alkaline trachyte deposit at Toongi in NSW, along with a peralkaline syenite deposit at Lovozero in Russia.

50 Barrie, J., 1965. Rare Earths, In: McLeod, I.R. (editor), Australian Mineral Industry: The Mineral Deposits. Bureau of Mineral Resources, Australia, Bulletin 72, 515–521.

51 <http://www.roskill.com/reports/minor-and-light-metals/rare-earths> (accessed August 2012).

52 Lynas Corporation Limited, 2011. Investor presentation May 2011. 38 pp.

53 Hastings Rare Metals Limited, 2012. ASX Announcement 13 August 2012, 2pp.

54 Cordier, D, 2012. Rare earths. In: Mineral commodity summaries 2012. United States Geological Survey, 128–129.

Industry Developments

Lynas Corporation Ltd: The Mount Weld deposit in WA occurs within a lateritic profile developed over an alkaline carbonatite complex. On 12 January 2012, Lynas reported Measured, Indicated and Inferred REO resources for the Central Lanthanide deposit at a cut-off of 2.5% REO of 14.949 Mt at 9.8% REO including Y_2O_3 . An updated resource for the Duncan Deposit in the weathered carbonatite complex stands at 8.992 Mt of Measured, Indicated and Inferred Resources at 4.8% REO including Y_2O_3 . In another part of the carbonatite complex there are 37.7 Mt of mostly Inferred Resources grading 1.07% Nb_2O_5 , total lanthanides at 1.16% and 0.09% Y_2O_3 , 0.3% ZrO_2 , 0.024% Ta_2O_5 , 7.99% P_2O_5 . The company completed the first stage of mining activities in 2008 and commenced construction of a concentration plant at Mount Weld and an advanced materials plant in Malaysia.

The concentration plant was commissioned in May 2011 and by the end of October, Lynas reported that the plant achieved a concentrate grade of 36.8% REO and a recovery of 64%. At the end of the June quarter 2012, more than 13 000 dry tonnes of concentrate containing more than 4800 tonnes of REO was bagged ready for export. Lynas also reported in its June 2012 quarterly report that the construction of phase 1 of the Lamp Advanced Materials Plant (LAMP) in Malaysia was completed and the commissioning progress was 64% complete. A decision by the Malaysian Atomic Energy Licensing Board to approve a Temporary Operating Licence for the LAMP is subject to appeals from parties opposing the project.

Arafura Resources Ltd: Nolans Bore rare earth-phosphate-uranium-thorium deposit is located 135 km northwest of Alice Springs in the NT. In June 2012, Arafura published a revised total Measured, Indicated and Inferred Resource figure of 47 Mt grading 2.6% REO, 11% P_2O_5 and 0.02% U_3O_8 down to a depth of 215 metres. According to Arafura, the distribution of the light REEs currently being considered for extraction, (La, Ce, Pr, and Nd) amount to 95% while the heavy REEs (Sm, Eu, Gd, Tb, Dy) amount to 4.23%. The company is planning to process the rare earth-phosphate-uranium-thorium ore concentrate from the Nolans Bore deposit at Whyalla in SA. Environmental studies are being conducted at Nolans Bore and the proposed rare earth processing plant at Whyalla.

On 7 August 2012, Arafura announced a definitive base case study which indicated that the Nolans Bore project could generate a net present value (NPV) of \$4.3 billion with a 10% discount rate and an internal rate of return of 30%, both calculated on an after tax basis over 20 years. On this basis, full capital payback will be achieved during the fourth year of operation⁵⁵.

Alkane Resources Ltd: The company's Dubbo Zirconia Project, based on the Toongi deposit 30 km south of Dubbo in NSW has a reported Measured Resource of 35.7 Mt and 37.5 Mt of Inferred Resources grading 1.96% ZrO_2 , 0.04% HfO_2 , 0.46% Nb_2O_5 , 0.03% Ta_2O_5 , 0.14% Y_2O_3 , 0.745% total REO, 0.014% U_3O_8 , and 0.0478% Th. On 16 November 2011, Alkane announced a Proved and Probable Reserve for the deposit of 35.93 Mt grading 1.93% ZrO_2 , 0.04% HfO_2 , 0.46% Nb_2O_5 , 0.03% Ta_2O_5 , 0.14% Y_2O_3 , and 0.74% total REO. On 19 September 2011, the company released results of a definitive feasibility study which indicated a NPV for the project of \$181 million at a processing rate of 400 kilotonnes per annum (ktpa) and \$1.207 billion at a processing rate of 1000 ktpa. In July 2012, Australian Zirconia Limited (AZL), a wholly owned subsidiary of Alkane Resources Ltd, signed a Memorandum of Understanding with Japan's Shin-Etsu Chemical Co Ltd to produce a suite of separated heavy and light REEs using the rare earth concentrates from the Dubbo Zirconia Project.

Kimberley Rare Earths Ltd: The company's Cummins Range carbonatite deposit occurs in the southeast part of the Kimberley region in WA. On 13 February 2012, Kimberley Rare Earths Ltd announced a revised Inferred Resource for the Cummins Range deposit of 4.9 Mt at 1.74% REO, 11.2% P_2O_5 145 ppm U_3O_8 and 48 ppm Th. The resource was calculated at a cut-off grade of 1% REO. The total REO was subdivided into 95.6% light REO (La, Ce, Pr, Nd), 4.1% middle REO (Sm, Eu, Gd, Tb, Dy) and 0.3% heavy REO (Ho, Er, Tm, Yb, Lu). A mineralogical investigation of the Cummins Range deposit by the CSIRO Minerals Down Under Flagship was completed during the March 2010 quarter with the principal rare earth bearing minerals being primary apatite and monazite and only subordinate amounts of secondary rare earth bearing minerals are present.

The company carried out a pit-optimisation study to produce a potential mining inventory for ore and waste for the project. Metallurgical testwork and associated mineralogical studies have been successfully completed both in Australia and China. Based on the study results, a mineral concentration flow sheet was established which confirmed the beneficiation process is able to achieve a concentrate grade of more than 15% total REO (TREO) and a recovery of

⁵⁵ Arafura Resources Limited, 2012. Arafura delivers Nolans project update. ASX announcement, 7 August 2012, 63pp.

more than 59% TREO. Three options for downstream processing and rare earth separation flow sheets were identified resulting in different rare earth product regimes. The results of study have been incorporated into a conceptual mine schedule for a preliminary evaluation study financial model.

Capital Mining Limited: Peralkaline granitic intrusions of the Narraburra Complex 177 km northwest of Canberra contain anomalous amounts of zirconium, REO and low concentrations of Th (73.2 Mt at 1250 grams per tonne (g/t) ZrO_2 , 146 g/t Y_2O_3 , 327 g/t REO, 45 g/t HfO_2 , 126 g/t NbO_2 , 54 g/t Ga_2O_3 , 118 g/t Li_2O and 61 g/t ThO_2 , Capital Mining Limited⁵⁶). In the March quarterly report in 2010, the owners of the project, Capital Mining Limited, reported that it was conducting metallurgical test to recover hafnium (Hf), Th, tantalum (Ta), Nb, Nd and Ce.

Hastings Rare Metals Limited: Historic exploration records reported that the Yangibana ferrocarnatite-magnetite-rare earth bearing dykes (ironstones) form part of the Gifford Creek Complex in WA. The dykes occur as lenses and pods and are typically the last stage of carbonatite fractionation and are enriched in REEs fluorite and U-Th mineralisation. The Yangibana prospect has a recorded historic resource of 3.5 Mt at 1.7% REO. The rare earths are in coarse grained monazite containing up to 20% Nd_2O_5 and 1600 ppm Eu_2O_3 . On 11 November 2011, Hastings published results of 38 surface samples collected from six prospects located in the western portion of the Yangibana group. The samples indicated a distribution profile of REO as shown in Table 14.

Table 14. Distribution profile of REO from six prospects in the western portion of the Yangibana group in Western Australia.

oxide	Light rare earths					Heavy rare earths				
	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Y	
% of TREO	18.6	42.9	5.9	25.5	4.0	0.8	1.4	0.3	0.6	

The REO distribution of the Yangibana ironstones is biased towards the light REO (LREO) but the proportion of Nd in the rare earth mix is relatively high at 25%. Neodymium is a key metal in industrial high strength magnets used in hybrid motor vehicles and wind turbines.

Hastings is considering a reverse-circulation drilling program to further define the previously drilled ironstone targets and establish JORC compliant resources in 2012.

Crossland Uranium Mines Limited: On 15 May 2012, the company reported resources for a new type of placer deposit, the Charley Creek deposit, containing zircon, monazite and xenotime. The company reported that the Charley Creek deposit is an alluvial outwash that comprises an Indicated Resource of 387 Mt containing 27 000 tonnes of xenotime, 161 000 tonnes of monazite and 196 000 tonnes of zircon. The xenotime and monazite were stated to contain about 114 000 tonnes of total REO (TREO). In addition, another 418 Mt of Inferred Resources was reported to hold about 121 000 tonnes of REO in about 31 000 tonnes of xenotime and 167 000 tonnes of monazite as well as 220 000 tonnes of zircon⁵⁷. An earlier report by Crossland, dated 5 April 2012, stated that the average equivalent monazite in the heavy mineral concentrate (HMC) (calculated from chemical analyses) is 87 372 g/t and equivalent xenotime is 8310 g/t while the HMC in the alluvium was 2.54%⁵⁸.

GBM Resources Ltd: On 9 August 2012, GBM announced an Inferred Resource of 187 Mt at 558 ppm TREO and 52 ppm Y_2O_3 for the Milo deposit located about 76 km east of Mount Isa and 22 km east of the Mary Kathleen uranium REO deposit. The Milo deposit is reported to be a polymetallic deposit with a range of metals including REEs, Y, copper, molybdenum and gold. GBM is currently conducting a scoping study including metallurgical testing to evaluate the deposit.

Marathon Resources Limited: In August 2005, the company reported that an Inferred Resource of 51 800 tonnes La-Ce is associated with its uranium deposit at Mount Gee, about 520 km north-northeast of Adelaide in SA. In July 2011, the South Australian Government established the Arkaroola Protection Area that will be reserved from operation under the South Australian Mining Act. In due course it is proposed to enact legislation protecting the Area and an application for World Heritage Listing will follow. As a consequence, future exploration and mining titles will not be granted in the Area.

56 Capital Mining Limited, 2011. Resource estimate update confirms rare earth potential Narraburra Project, NSW. ASX announcement, 9 November 2011, 4pp.

57 Crossland Uranium Resources Ltd, 2012. Quarterly report for period ended June 30, 2012, 5pp.

58 Crossland Uranium Resources Ltd, 2012. Announcement to the Australian Securities Exchange 5 April 2012, 3pp.

BHP Billiton Limited: About 53 Mt of the Submarginal and Inferred Resources are in the Olympic Dam iron oxide-copper-gold deposit in SA (predominantly 0.2% La and 0.3% Ce) and are not currently economic.

Chinalco Yunnan Copper Resources Ltd: REEs have been intersected in drill holes at the Elaine 1 deposit, about 80 km south of the Mary Kathleen deposit in northwest Qld. Chinalco has published resources for copper and gold for Elaine 1 deposit but resources of REO have not been released for the deposit. The historic uranium mine of Mary Kathleen is essentially a uranium-rare earths skarn deposit which has a remnant resource in tailings of about 5.5 Mt at 6.4% REO +Y. Commonly occurring REE minerals in the original deposit were stillwellite and allanite while other REE-bearing minerals included apatite, titanite and garnet.

Metallica Minerals Limited: Metallica's scandium resources are located within its lateritic Ni-Co deposits near Greenvale about 190 km west-northwest of Townsville in Qld. The company's Kokomo deposit is 50 km north-northeast of Greenvale and the Lucknow deposit is two kilometres south of Greenvale. On 19 January 2011⁵⁹, Metallica reported Indicated and Inferred Resources for the Lucknow deposit totalling 6.24 Mt grading at 169 g/t Sc, 0.2% Ni and 0.04% Co delineated at a cut-off-grade of 70 g/t Sc. The company's Measured, Indicated and Inferred Resource for the Kokomo deposit totals 9 Mt grading 109 g/t Sc, 0.24% Ni and 0.03% Co associated with a lateritic Ni-Co deposit of 16.3 Mt at 0.67% Ni, 0.12% Co and 36 g/t Sc. The total Sc resource for the two deposits amounts to 15.1 Mt at 133 g/t Sc, 0.22% Ni, 0.04% Co. The contained scandium metal in the two deposits amounts to approximately 2000 tonnes Sc⁶⁰.

The Lucknow deposit includes a high grade zone at a cut-off-grade of 120 g/t Sc measuring 4.12 Mt of Indicated and Inferred Resources at 206 g/t Sc, 0.21% Ni and 0.05% Co.

Metallica also announced on 4 July 2012 that a scoping study confirmed technical and financial viability for the proposed development of the Nornico project and its associated Greenvale, Lucknow and Kokomo deposits, demonstrating that existing nickel-cobalt and scandium resources can support a 75 000 tpa operation over a 20-year mine life with an estimated capital expenditure of \$597 million. The average annual operating costs was estimated at \$138 million with a NPV of \$402 million (pre-tax, 10% real discount rate, 100% equity, 20% capital expenditure contingency) and an internal rate of return of 16.4% average annual operating margin of \$179 million. Metallica is progressing the scoping study to a pre-feasibility study stage. On 27 July 2012, Metallica changed the name of its Nornico project to Sconi.

Jervois Mining Ltd: In June 2005, the company reported that its Nyngan lateritic nickel-cobalt-scandium-platinum deposit in NSW had a resource of 16 Mt at 0.87% Ni and 0.06% Co. A Sc-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718 Mt at 274 ppm Sc and Indicated Resources of 9.294 Mt at 258 ppm Sc. Jervois formed a joint venture agreement with EMC Metals Corporation of Canada which is conducting a three phased test-work to study the recovery of scandium from lateritic ores at Nyngan. By the end of 2011, EMC reported results of a semi-continuous pilot plant included the following:

- Conventional contained sulphuric acid bake and water leach systems, at atmospheric pressure, demonstrated scandium recoveries averaging 75%.
- Conventional solvent extraction on the pregnant leach solution, demonstrated scandium recoveries exceeding 99%.
- Final stage precipitation of scandium oxide, focussed on highest combined purity and recovery, demonstrated scandium recoveries of 97.5%, at purity levels of 97.5% Sc₂O₃.
- Overall recovery results were 70 to 80%, based on ore type (limonite or saprolite).

EMC reported in their annual report for 2011⁶¹ that key elements of environmental site work on the Nyngan Scandium Project have been completed and a Conceptual Project Development Plan (CPDP) has been submitted to the NSW regulators. The CPDP submission forms the basis for an Environmental Impact Study.

59 Metallica Minerals Limited, 2011. Major resource upgrade as Queensland tri-metal project celebrates milestone. ASX Release, 19 January 2011.

60 Metallica Minerals Limited, 2011. Quarterly report to 30 Sept 2011.

61 EMC Metals Corp., 2011. Annual Report Pursuant to Section 13 or 15(d) of The Securities Exchange Act of 1934 for the fiscal year ended December 31, 2011.

Krucible Metals Ltd: Inferred phosphate and REE resources have been recently published for the Korella phosphate-yttrium deposit as 13.72 Mt at 0.70 kg/t Y_2O_3 and Nd and Dy are also reported to be present, but their resources have not been estimated (Krucible Metals Ltd, 2011⁶²). The Korella deposit also has an Inferred Resource of 8.3 Mt at 27.36% P_2O_5 at a cut-off grade of 20% P_2O_5 (Krucible Metals Ltd, 2010). The anomalous zone of yttrium enrichment at Korella appears to remain open towards the Duchess deposit to the north. There is little published data in regard to REE resources in phosphorite in Australia. Total phosphate resources in the Georgina Basin are considered to be of the order of four billion tonnes (Lottermoser, 1991⁶³), but total REE contents in the phosphorites are generally much less than 1000 ppm.

62 Krucible Metals Ltd, 2011. ASX announcement, 10th October 2011. Inferred Resource update for Korella yttrium deposit. Announcement to the Australian Securities Exchange, 13 pp.

63 Lottermoser, B.G., 1991. Rare earth element resources and exploration in Australia. The Australasian Institute of Mining and Metallurgy, Proceedings 296, Number 2, November 1991, 49–56.

Shale Oil

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Oil shale is organic-rich shale that yields substantial quantities of oil (normally referred to as shale oil) and combustible gas by heating (retorting) and distillation. The organic material in oil shale is called kerogen, which, under appropriate conditions in the Earth's crust, can be a precursor to conventional oil reservoirs. One tonne of commercial grade oil shale may yield from about 100 to 200 litres of oil.

Resources

The majority of oil shale resources of commercial interest are located in a series of narrow and deep extensional-basins near Gladstone and Mackay, and further north near Proserpine in central Queensland (Qld). These are thick Cenozoic lacustrine (lake-formed) deposits that are relatively easy to mine and process compared to carbonate-rich oil shales (marls) elsewhere in the world. The Permian Galilee and Bowen Basins in Qld contain oil shale associated with coal measures. Oil shales occur in the Cretaceous Toolebuc Formation of the Eromanga Basin in northwest Qld. Oil shale deposits of varying quality are located in the Sydney Basin, New South Wales (NSW), at the Latrobe tasmanite deposit in northern Tasmania (Tas), at Eyre Peninsular in South Australia (SA) and within an oil shale-heavy mineral sand deposit in southern Western Australia (WA).

Resource estimates were reviewed to take into account the historic nature of the estimates and losses resulting from processing. Australia's shale oil resources estimates are for **recoverable** shale oil. Paramarginal and Submarginal Demonstrated Resources of shale oil as at the end of 2011 are 213 gigalitres (GL) (about 1340 million barrels) and 2074 GL (about 13 050 million barrels) respectively. Both figures are unchanged from 2010.

An Inferred Resource is estimated to be 1272 GL (about 8000 million barrels), also unchanged from 2010. This figure excludes the total potential shale oil resources of the Toolebuc Formation (Qld) estimated to be around 245 000 GL. This estimate was made by Geoscience Australia's predecessor, the Bureau of Mineral Resources, and the CSIRO in 1983⁶⁴. The research project undertook detailed geological, petrophysical and geochemical examination of the oil shales of the Toolebuc Formation. The project aimed to investigate and develop methods to assist government and industry to assess the potential of the sedimentary sequence as a possible future source of oil shale and to develop an understanding of geological controls and the distribution of oil shale within the Toolebuc Formation. A resource assessment of around 245 000 GL was based on productive oil shale covering an area of 484 000 square kilometres and ranging from 6.5 to 7 metres (m) thick with a specific gravity of 1.9 and yielding an average 37 litres of oil per tonne oil shale.

Exploration

In Queensland, the majority of exploration activity has been in care and maintenance since the Queensland Government announced a two-year review into the oil shale industry and a 20-year moratorium (recently lifted) on oil shale development in the Whitsunday region around Proserpine. Previously, exploration was predominantly focused near Gladstone and Mackay in central Qld and in northwest Qld. In Tasmania, Boss Energy Ltd is continuing to undertake exploration work southeast of Devonport at the Latrobe oil shale deposit and Eagle Nickel Ltd is assessing exploration tenements adjacent to the Latrobe project. Data associated with shale oil exploration are not available.

Production

There was no oil being extracted from oil shale in Australia between 2004 and September 2011. From 2000 to 2004, the previous demonstration processing plant at the Stuart deposit (Qld) produced more than 1.5 million barrels of oil using a horizontal rotating kiln process (Alberta Taciuk Process). The facility has been dismantled and the site remediated.

In September 2011, Queensland Energy Resources Ltd (QER) produced its first crude oil from its demonstration Paraho II™ vertical shaft kiln processing plant at the Stuart deposit near Gladstone, central Qld. The oil is being stored in secure tanks on-site, awaiting commissioning of the oil upgrading unit (refinery).

64 Ozimic, S. and Saxby, J.D., 1983. Oil Shale Methodology: An examination of the Toolebuc Formation and the laterally contiguous time equivalent units, Eromanga and Carpentaria Basins. Bureau of Mineral Resources and CSIRO research project.

The QER demonstration plant achieved stable production capacity of 6000 tonne of shale per day and oil yield totalling 4500 barrels per stream day while maintaining product quality and adhering to Environment Protection Authority emissions limits. The oil products from the demonstration plant were Ultra Low Sulphur Naphtha (ULSN) 55% to 60% and Light Fuel Oil (LFO) 40% to 45%. The ULSN, which can be used to make petrol, diesel and jet fuel, has a sulphur content of less than one part per million (ppm). To put this into perspective, from 1 January 2008, the Fuel Standard (Petrol) Determination regulated that the maximum content of sulphur is 50 ppm in premium unleaded petrol.

World Ranking

The 2010 Survey of Energy Resources by the World Energy Council (WEC) reported that total world **in-place** resources of shale oil are estimated to be 4.8 trillion barrels. The largest known deposit is in the western USA (3 trillion barrels in-place resource), with other important deposits in China, the Russian Federation, the Democratic Republic of the Congo, Brazil, Italy, Morocco, Jordan and Estonia, as well as Australia. Only Estonia, China and Brazil produce shale oil. The WEC survey reported that total oil production at the end of 2008 was about 1165 ML, with Estonia producing 445 ML, China 470 ML and Brazil 250 ML.

Industry Developments

In August 2008, the Queensland Premier announced a review into whether oil shale deposits can be developed in an environmentally acceptable way. The review report is to be prepared no earlier than two years from the commencement of operation of the QER Stuart facilities in order to allow that research to come to fruition. Queensland Energy Resources produced its first crude oil in September 2011 and submitted a final report to the Queensland Government in September 2012 indicating that there were no reportable environmental incidents at the plant during all phases of construction, commissioning and operations, and that there were no community complaints about odour and noise.

In November 2008, Queensland Government amendments to the *Mineral Resources Act 1989 (Qld)* placed a 20-year moratorium on oil shale mining in the Whitsunday region around Proserpine. The granting of new tenures and variation of existing entitlements relating to oil shale were suspended until the state government considered the report on an oil shale review. In February 2013, the Queensland Government lifted the moratorium on shale oil except for the McFarlane oil shale deposit. The government will now consider all projects on a case-by-case basis.

In Queensland, several companies have either scaled back investment or revised projects. These companies include:

- Australian Thermal Solution Pty Ltd, a subsidiary of Blue Ensign Technologies Ltd (Julia Creek Project (south), northwest Qld), which, in June 2009, was planning to build a demonstration plant to test the thermal solution technology (Rendall Process), a thermal conversion and hydrogenation, followed by supercritical solvent extraction.
- Greenvale Mining NL (Alpha project, Qld), which continues to review the viability of Vertical Retort Torbanite (VRT) processing technology being developed by a South African based company.
- Xtract Energy Plc (Julia Creek Project (north), northwest Qld) has scaled back investment in the development of the Xtract technology, a hydrogen and supercritical solvent extraction process.

In Tasmania, Boss Energy Ltd engaged the Chinese company, Fushun Mining Group (FMG), to carry out tests on a 500 kg tasmanite oil shale sample from the Latrobe project using Fushun vertical retort technology to determine physical and chemical properties and key operating parameters. Results were positive returning a 9.5% crude oil content and very similar chemical and physical properties to Fushun's oil shale. Boss Energy has written a letter of intent with respect to forming a Joint Venture agreement with FMG and is awaiting a response.

Tantalum

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The main use of tantalum (Ta) is in the manufacture of capacitors required for the electronics and telecommunications industries. Because they are small and have high reliability, these capacitors are used in miniaturised electronic circuits, mainly in mobile phones. Because of its anti-corrosive properties tantalum metal is used in the chemical industry in applications such as tantalum carbide in tools for metal cutting and machining as well as in metal alloys in the aerospace and electricity-generating industries. Overall, approximately 60% of annual world consumption of tantalum is used in the electronics industry, with more than half of this currently used in the manufacture of mobile phones.

Tantalum minerals have more than 70 different chemical compositions, of which tantalite ((Fe,Mn)Ta₂O₆), microlite (CaTa₂O₆), and wodginite (Mn(Sn,Ta)(Ta,Nb)₂O₆) are of greatest economic importance. It is common practice to name any mineral concentrate containing tantalum as tantalite.

Australia has historically been the world's largest producer of tantalum (as tantalite concentrates), providing approximately half of the world's mine output through mining operations at Greenbushes 250 kilometres (km) south of Perth, Western Australia (WA) and at Wodgina 100 km south of Port Hedland, WA.

For location of tantalum deposits refer to Fig. 14 in the Tin chapter

Resources

In WA, granitic rare-metal pegmatites are the dominant host rock for primary tantalum mineralisation. The only exceptions are the carbonatite type deposit at Mount Weld in the eastern goldfields of WA and an unusual form of subalkaline granite–syenite mineralisation at the Brockman-Hastings deposit, southeast of Halls Creek, WA.

Australia's Economic Demonstrated Resources (EDR) are estimated to be 62 kilotonnes (kt) of tantalum in 2011, a 17% increase on 2010 resource of 53 kt. Of these, 86% are in WA and 14% in New South Wales (NSW). More than 92% of the EDR in WA are associated with Global Advanced Metals' (formerly Talison Tantalum) Greenbushes and Wodgina deposits. The remaining EDR occur at Mount Cattlin, Mount Deans, Dalgaranga, Arthur River and the Brockman-Hastings (formerly known as Brockman) deposits (all in WA). In NSW, all the EDR are associated with the Toongi deposit.

The Brockman-Hastings Rare Metals deposit, which is owned by Augustus Minerals Limited, is located 18 km southeast of Halls Creek, WA. It is hosted by a fine-grained volcanoclastic unit (informally known as the Niobium Tuff) within a sequence of thick volcanic-sedimentary rocks. The Niobium Tuff can be traced over a strike length of 3.5 km and varies in width up to 35 metres (m). The deposit has a Joint Ore Reserve Committee (JORC) Code compliant resource of 36.2 million tonnes (Mt) grading 0.89% ZrO₂, 0.36% Nb₂O₅, 0.018% Ta₂O₅ comprising an Indicated Resource of 27.1 Mt grading 0.018% Ta₂O₅ and an Inferred Resource of 9.1 Mt grading 0.018% Ta₂O₅.

The Toongi deposit, 20 km south of Dubbo in NSW, accounts for 14% of tantalum EDR. The deposit is a sub-volcanic intrusive trachyte body (vertical) with dimensions of approximately 900 by 600 m, which has been drilled out to a depth of 55 m to provide a Measured Resource of 35.7 Mt grading 0.03% Ta₂O₅, and between 55 and 100 m for an Inferred Resource of 37.5 Mt grading 0.03% Ta₂O₅.

Subeconomic Demonstrated Resources account for about 29% of total Demonstrated Resources. The Paramarginal and Submarginal Resources amount to 18 kt, an increase from 15 kt in 2010. Western Australia is the largest holder of Paramarginal Resources with 61% followed by NSW with 39%. All the Submarginal Resources occur in WA.

Inferred Resources totalled 29 kt compared to 30 kt in 2010, which results from marginal upgrading the resources at Brockman-Hastings Rare Metals deposit and the removal from the national inventory of historical estimates which pre-date the JORC Code and so do not comply with its requirements. Western Australia and NSW account for 69% and 31% of Inferred Resources respectively.

Accessible EDR

All of Australia's EDR of tantalum is accessible.

JORC Reserves

The Joint Ore Reserve Committee (JORC) Code reserves comprise total tantalum in Proved and Probable Ore Reserves as defined in the JORC Code. In 2011, JORC Code reserves of 29 kt accounted for approximately 47% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

Data on exploration expenditure for tantalum are not available.

Production

Western Australian Department of Mines and Petroleum has not reported tantalum production figures for 2011. However Galaxy Resources reported production from Mount Cattlin deposit of 0.465 kt of tantalum concentrate containing 3.3% Ta₂O₅.

World Resources and Production

Based on estimates published by the United States Geological Survey (USGS) and Geoscience Australia, the world resources of tantalum in 2011 totalled 131 kt. The world's largest holder of tantalum resource is Brazil with an estimated 65 kt, followed by Australia with 62 kt and Mozambique at 3 kt.

Using USGS data, Geoscience Australia estimated world production of tantalum in 2011 to be 790 tonnes (681 tonnes in 2010). Production in 2011 was dominated by Brazil, with 180 tonnes, which amounted to about 22% of world output. According to the USGS, other main producers were Mozambique with 120 tonnes, Rwanda with 100 tonnes and Canada with 25 tonnes.

Industry Developments

Global Advanced Metals' (GAM) recommenced mining at its **Wodgina** mine in January 2011 following it being on care and maintenance since December 2008 as a result of the global financial crisis. Throughout 2009 and 2010, the company continued to process tantalum pentoxide from its ore stockpiles. Although the initial recommencement mining rate will be at 700 000 pounds a year, the Wodgina mine has a capacity to produce 1.4 million pounds a year of tantalum pentoxide (Ta₂O₅) from tantalum-bearing pegmatite ores at the Mount Cassiterite and South Tinstone open cut mines.

GAM's **Greenbushes** operations in WA includes an open cut and an underground mine, primary and secondary tantalum processing plants, a tin smelter and a lithium plant. The company's primary tantalum plant remains on care and maintenance. Its secondary processing plant treats stockpiles of primary tantalum concentrates from the Wodgina mine. Processing of newly mined Wodgina ore commenced in mid 2011. The company's Greenbushes tin smelter is closed and its lithium operation produces various grades of spodumene products (see Lithium Chapter).

In early 2011, Traxys Tantalum LP, a member of the Traxys Group, agreed to acquire a 20% interest in GAM subject to approval by the Australian Foreign Investment Review Board.

During the December quarter 2010, Galaxy Resources Limited commenced production from the Dowling Pit at its **Mount Cattlin** lithium-tantalum project (hard-rock spodumene) north-northeast of Ravensthorpe, WA. At full production, the project is expected to produce 137 000 tonnes a year of spodumene concentrate grading 6% lithium oxide (Li₂O) and 56 000 pounds a year of contained Ta₂O₅ in concentrate. In December 2010, Galaxy Resources entered an agreement with GAM to supply it with 200 000 pounds of its Mount Cattlin Ta₂O₅ ore over 5 years, which will upgrade the material at GAM's Greenbushes plant. The Mount Cattlin deposit has a reported JORC Code compliant resource of 18.188 Mt with an average grade of 1.08% Li₂O and 156 parts per million of Ta₂O₅ containing an estimated 197 000 tonnes of Li₂O and 6.26 million pounds of Ta₂O₅ above a cut-off grade of 0.4% Li₂O.

A technical report in December 2011 prepared by SNOWDEN for GAM recommended further exploration and drilling to determine the extent and grade of mineralisation in deeper parts of pegmatite bodies.

A demonstration pilot plant run by Alkane Resources Ltd at the ANSTO Minerals Lucas Heights operation in Sydney, NSW, has recovered several tonnes of zirconia concentrate, niobium-tantalum concentrate and yttrium-rare-earth concentrate. The source material has come from Alkane Resources's Dubbo Zirconia Project based on the Toongi deposit 20 km south of Dubbo, NSW. The company is in the advanced stages of developing a memorandum of understanding with a niobium consumer to form a joint venture to produce ferro-niobium from niobium concentrate for specialised alloy markets.

Thorium

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Thorium oxide (ThO₂) has one of the highest melting points of all oxides (3300 °C) and has been used in light bulb elements, lantern mantles, arc-light lamps and welding electrodes as well as in heat resistant ceramics.

Thorium can be used as a nuclear fuel through breeding to ²³³U. There is no significant demand for thorium resources currently and any large-scale commercial demand is expected to be dependant on the future development of thorium fuelled nuclear reactors. Several reactor concepts based on thorium fuel cycles are under consideration, but a considerable amount of development work is required before it can be commercialised.

India has been developing a long-term three stage nuclear fuel cycle to utilise its abundant thorium resources. The construction of a 500 megawatt electric (MWe) prototype fast breeder reactor at Kalpakkam, near Madras, was about 81% complete in November 2011. It will have a blanket with thorium and uranium to breed fissile ²³³U and plutonium respectively. Six more such fast breeder reactors have been announced for construction and this project will take India's thorium program to stage 2.

In stage 3, Advanced Heavy Water Reactors (AHWRs) burn ²³³U and plutonium with thorium to derive about 75% of the power from thorium. For each unit of energy produced, the amount of long-lived minor actinides generated is nearly half of that produced in current generation Light Water Reactors. In mid 2010, a pre-licensing safety appraisal had been completed by the Atomic Energy Regulatory Board (AERB) and site selection was in progress. Construction of the AHWR is anticipated to commence in 2014, but full commercialisation of thorium reactors is not expected before 2030. The AHWR can be configured to accept a range of fuel types, including enriched U, U-Pu MOX, Th-Pu MOX, and ²³³U-Th MOX in full core.

In September 2009, India announced an export version of the AHWR, the AHWR- Low Enriched Uranium (LEU) version. This design will use LEU plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to ²³³U). This version can meet the requirement also of medium sized reactors in countries with small grids along with the requirements of next generation systems (World Nuclear Association 2011⁶⁵; Kakodkar 2009)⁶⁶.

In January 2011, the China Academy of Sciences launched a research and development program on Liquid Fluoride TR, known at the academy as the thorium-breeding molten-salt reactor (Th-MSR or TMSR). A 5MWe MSR is believed to be under construction at Shanghai, with an operational target date of 2015.

Atomic Energy of Canada Ltd (AECL) has reported that some countries are assessing the use of thorium fuels in existing CANDU 6 (700MWe class) reactors. In July 2009, AECL signed a second phase agreement with four Chinese entities to develop and demonstrate the full-scale use of thorium fuel in the CANDU 6 reactors at Qinshan in China. This was supported in December 2009 by an expert panel appointed by CNNC and comprising representatives from China's leading nuclear academic, government, industry and research and development organisations. The panel also recommended that China consider building two new CANDU units to take advantage of the design's unique capabilities in utilising alternative fuels⁶⁷. A demonstration 'High Temperature Reactor-Pebble Modules' (HTR-PM) of 210MWe (two reactor modules) is being built at Shidaowan in Shandong province. A further 18 units of 210MWe each are planned and followed by increases in the size of the 210MWe unit modules including the introduction of thorium in fuels.

Resources

At end of December 2011, Australia's total indicated and inferred in-situ resources of thorium amounted to about 532 000 tonnes. Because there is no publicly available data on mining and processing for these resources, the recoverable resource of thorium is not known. However, assuming an arbitrary figure of 10% for mining and processing losses in the extraction of thorium, the recoverable resources of Australia's thorium could amount to about 478 800 tonnes.

65 World Nuclear Association, 2012. Nuclear Power in India. Country briefings, July 2012, 28pp.

66 Kakodkar A, 2009. Statement by Dr Anil Kakodkar, Chairman of the Atomic Energy Commission and leader of the Indian delegation, IAEA 53rd General Conference, Vienna, 16 September 2009.

67 World Nuclear Association, 2012. China Nuclear Fuel Cycle. Country briefings, July 2012, 7pp.

Because there is no established large-scale demand and associated costing information, there is insufficient information to determine how much of Australia's thorium resources are economically viable for electricity generation in thorium nuclear reactors.

There are no comprehensive detailed records on Australia's thorium resources because of the lack of large-scale commercial demand and a paucity of the required data.

Thorium resources in heavy mineral sand deposits

Most of the known thorium resources in Australia are in the rare earth-thorium phosphate mineral monazite within heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Prior to 1996, monazite was being produced from heavy mineral sand operations and exported for extraction of rare earths. However, in current heavy mineral sand operations, the monazite is generally returned to the pit in dispersed form, as required by mining regulations. This dispersion is carried out to avoid a concentration of radioactivity when rehabilitating the mine site to an agreed land use. In doing so, the rare earths and thorium present in the monazite are negated as a resource because it would not be economic to recover the dispersed monazite for its rare earth and thorium content. The monazite content of heavy mineral resources is seldom recorded by mining companies in published reports. However, in June 2012, Astron Corporation Ltd noted in an investor presentation that it intends to export 10 000 tonnes of monazite per year to China from its Donald heavy mineral sand deposit in Victoria⁶⁸.

Most of the known resources of monazite are in Victoria and Western Australia (WA). Heavy mineral sands are being mined in the Murray basin deposits at Ginkgo and Snapper in New South Wales (NSW) and at Douglas in Victoria. In WA, mining of heavy minerals is taking place at Eneabba, Cooljarloo, Dardanup and Gwindinup.

Using available data, Geoscience Australia estimates Australia's monazite resources in the heavy mineral deposits to be around 7.4 million tonnes (Mt). The data on monazite and the thorium content in the monazite in the mineral sand resources is very variable, but the available sources include:

- analyses for monazite and thorium in published and unpublished reports;
- published and unpublished analyses of thorium content in exported monazite concentrates; and
- monazite and thorium analyses on heavy mineral sand deposits in company reports on open file available at some State Geological Surveys.

68 Stockdale, H. and Nielsen, M., 2012. Astron Corporation Limited investor presentation. June 2012, 35pp.

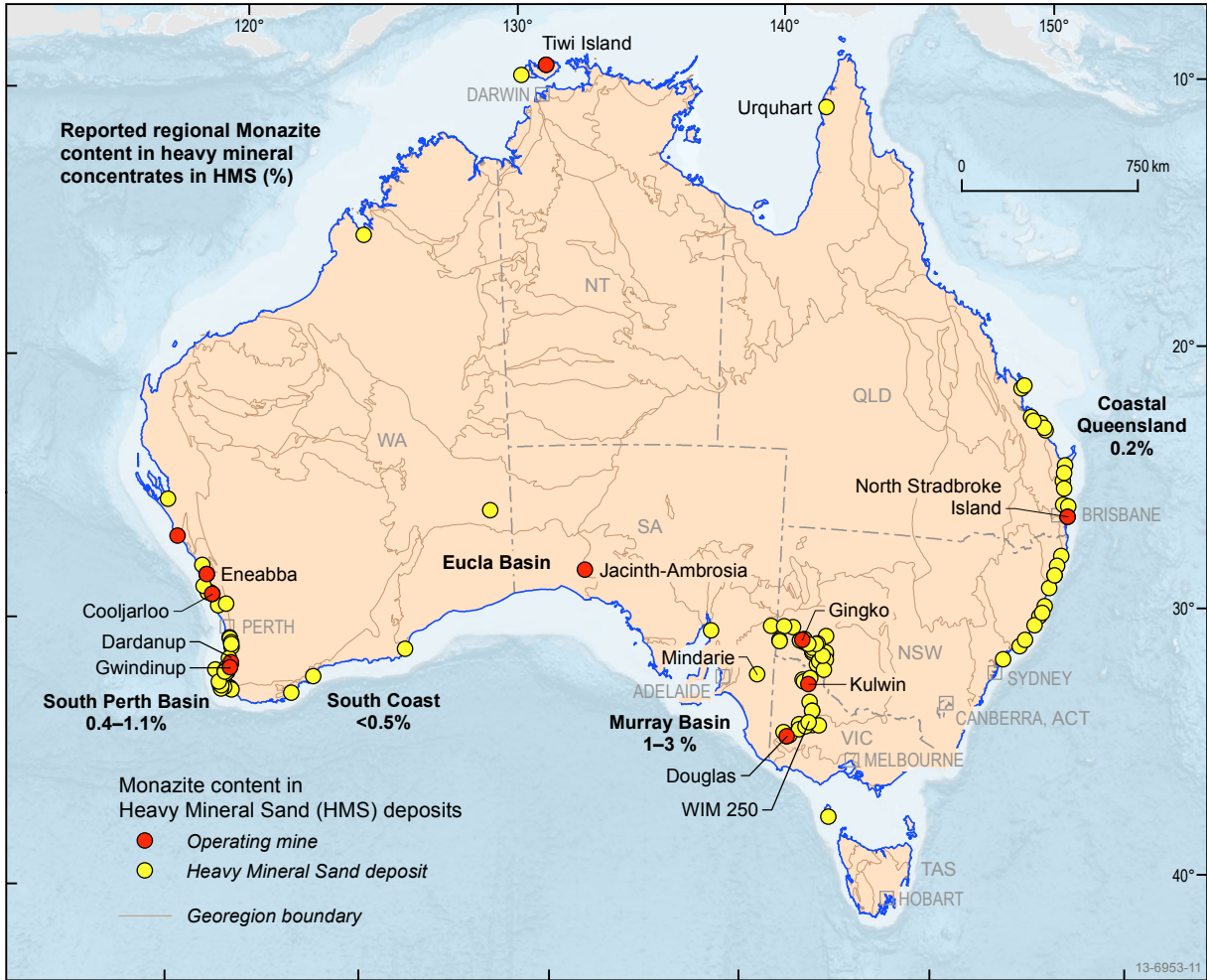


Figure 12. Reported regional monazite content in heavy mineral concentrates of heavy mineral sand deposits in Australia.

Information from these sources was applied to resource data on individual heavy mineral sand deposits to estimate the thorium resources in these deposits. Where local data on the monazite and thorium were not available, regional data were applied to individual deposits to estimate their monazite and thorium resources. Using this information, Australia's inferred in situ thorium resources in the mineral sands were estimated to be around 371 000 tonnes. The regional distribution of monazite in heavy mineral sands is shown in Figure 12 and the location of various types of deposits containing thorium and the regional distribution of estimated thorium resources is shown in Figure 13.

Resources for a new type of placer deposit, the Charley Creek deposit, containing zircon, monazite and xenotime was reported on 15 May 2012 by Crossland Uranium Mines Ltd. The Charley Creek deposit was reported by the company as an alluvial outwash with comprises an Indicated Resource of 387 Mt containing 27 000 tonnes of xenotime, 161 000 tonnes of monazite and 196 000 tonnes of zircon. The xenotime and monazite were stated to contain about 114 000 tonnes of total rare earth oxides. In addition, another 418 Mt of Inferred Resources was reported to hold about 121 000 tonnes of rare earth oxides in about 31 000 tonnes of xenotime and 167 000 tonnes of monazite as well as 220 000 tonnes of zircon. The thorium content in the xenotime and monazite was not stated.

Apart from heavy mineral sand deposits, thorium can be present in other geological settings such as alkaline intrusions and complexes, including carbonatites, and in veins and dykes. In these deposits, thorium is usually associated with other commodities such as rare earths, zirconium, niobium, tantalum and other elements. The more significant deposits are described in the following sections.

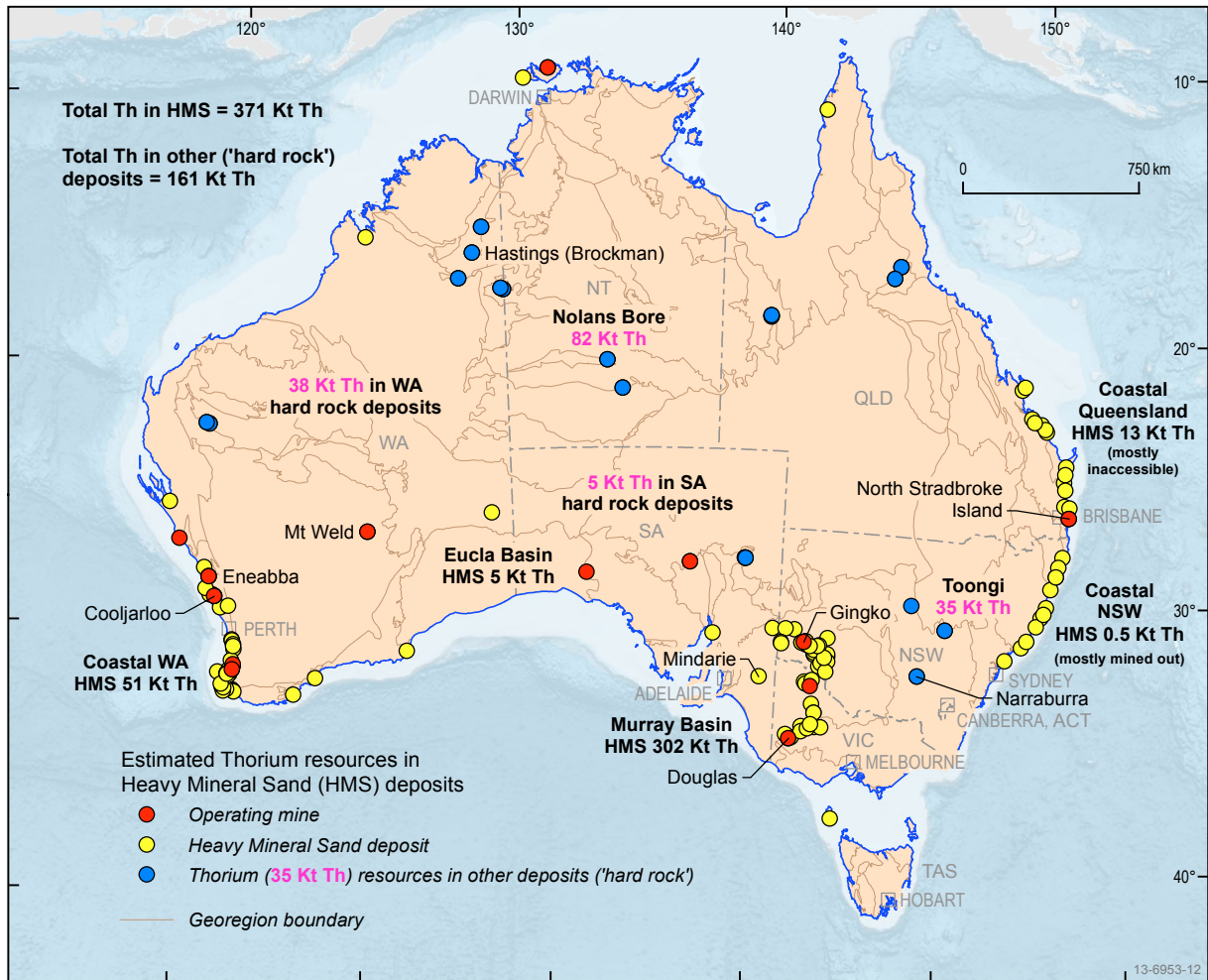


Figure 13. Distribution of thorium resources (in situ) in heavy mineral and other types of deposits.

Thorium resources in vein-type deposits

Arafura Resources Ltd: Nolans Bore rare earth element-phosphate-uranium-thorium deposit is located 135 kilometres (km) northwest of Alice Springs in the Northern Territory (NT). The mineralisation is hosted in fluorapatite veins and dykes. This deposit contains about 81 800 tonnes of Th in 30.3 Mt of Measured, Indicated and Inferred Resources grading 2.8% rare earth oxides (REO), 12.9% P₂O₅, 0.02% U₃O₈ and 0.27% Th. Arafura is considering processing the rare earth-phosphate-uranium-thorium ore concentrate from the Nolans Bore deposit at Whyalla in South Australia. The thorium content in the concentrate will be separated as an iron-thorium precipitate and transported back to the Nolans Bore mine site for long-term storage as a possible future energy source. In June 2012, Arafura published a revised total Measured, Indicated and Inferred Resource figure of 47 Mt grading 2.6% REO, 11% P₂O₅ and 0.02% U₃O₈. The thorium grade was not published but assuming a similar thorium grade of 0.27% Th, the upgraded resource could contain thorium in the order of 127 000 tonnes.

Thorium resources in alkaline rock complexes

Alkane Resources Ltd: The Toongi zirconium-niobium-rare earth element deposit occurs within an alkaline trachyte plug about 30 km south of Dubbo in NSW. The deposit has a Measured Resource of 35.7 Mt and 37.5 Mt of Inferred Resources grading 1.96% ZrO₂, 0.04% HfO₂, 0.46% Nb₂O₅, 0.03% Ta₂O₅, 0.14% Y₂O₃, 0.745% total REO, 0.014% U₃O₈, and 0.0478% Th, giving a total of about 35 000 tonnes contained Th. In November 2011, Alkane announced Proved and Probable Reserves for the deposit of 35.93 Mt grading 1.93% ZrO₂, 0.04% HfO₂, 0.46% Nb₂O₅, 0.03% Ta₂O₅, 0.14% Y₂O₃, and 0.73% total REO. The company also released results of a definitive feasibility study for the project that excluded the production of thorium. The financial analysis indicated a net present value for the project of \$181 million at a processing rate of 400 kilotonnes per annum (ktpa) and \$1.207 billion at a processing rate of 1000 ktpa. In July 2012, Australian Zirconia Limited (AZL), a wholly owned subsidiary of Alkane Resources Ltd, signed a Memorandum

of Understanding with Japan's Shin-Etsu Chemical Co Ltd to produce a suite of separated heavy and light rare earths using the rare earth concentrates from the Dubbo Zircon Project.

Hastings Rare Metals Limited: Other alkaline complexes with known rare earth and thorium mineralisation include Brockman (now renamed 'Hastings') in WA. It is a large, low-grade zirconium-niobium-rare earth element (Zr-Nb- REE) deposit hosted in altered trachytic tuff of Paleoproterozoic age. On 8 September 2011, Hastings reported 36.2 Mt of Indicated and Inferred Resources grading 8.86 parts per million (ppm) ZrO_2 , 3.55 ppm Nb_2O_5 , 182 ppm Ta_2O_5 , 110 ppm Ga_2O_3 , 318 ppm HfO_2 , 186 ppm Dy_2O_3 , 1120 ppm Y_2O_3 , 2102 ppm total REO and 1802 ppm heavy REO. Historic company reports on open file on the Geological Survey of Western Australia WAMEX database show analyses for thorium in six separate drill hole intersections (in tuffs) of 16 metres (m) to 28 m averaging from 259-371 ppm Th (Western Australia Geological Survey WAMEX database report A 40991).

Capital Mining Limited: The peralkaline granitic intrusions of the Narraburra Complex 177 km northwest of Canberra contain anomalous amounts of zirconium, REO and low concentrations of Th (73.2 Mt at 1250 grams per tonne (g/t) ZrO_2 , 146 g/t Y_2O_3 , 327 g/t REO, 45 g/t HfO_2 , 126 g/t Nb_2O_5 , and 61 g/t ThO_2 ; Capital Mining Limited Prospectus 2006). The thorium oxide (ThO_2) content amounts to 4465 tonnes (2420 tonnes Th). In the March quarterly report in 2010, Capital Mining reported that it was conducting metallurgical test to recover hafnium (Hf), Th, tantalum (Ta), niobium (Nb), neodymium (Nd) and cerium (Ce).

Thorium resources associated with carbonatite intrusions

Data on the thorium content of carbonatite intrusions in Australia is sparse. Mount Weld and Cummins Range in WA have the most significant rare earth resources reported for carbonatites in Australia to date, with both having some thorium content.

Lynas Corporation Ltd: The Mount Weld deposit in WA occurs within a lateritic profile developed over an alkaline carbonatite complex. On 12 January 2012, Lynas reported Measured, Indicated and Inferred REO resources for the Central Lanthanide deposit at a cut-off of 2.5% REO of 14.949 Mt at 9.8% REO including Y_2O_3 . The ThO_2 content of the deposit is estimated to be 712 ppm, which equates to 626 ppm Th (personal communication B Shand, Lynas Corporation Ltd (Lynas) 17 June 2009).

An updated resource for the Duncan Deposit in the weathered carbonatite complex stands at 8.992 Mt of Measured, Indicated and Inferred Resources at 4.8% REO including Y_2O_3 . The ThO_2 content is estimated to be 441 ppm (388 ppm Th). In another part of the carbonatite complex there are 37.7 Mt of mostly Inferred Resources grading 1.07% Nb_2O_5 , total lanthanides at 1.16% and 0.09% Y_2O_3 , 0.3% ZrO_2 , 0.024% Ta_2O_5 , 7.99% P_2O_5 and a ThO_2 content of 479 ppm (421 ppm Th).

Kimberley Rare Earths Ltd: On 13 February 2012, Kimberley Rare Earths Ltd announced a revised Inferred Resource for the Cummins Range in WA carbonatite deposit of 4.9 Mt at 1.74% REO, 11.2% P_2O_5 , 145 ppm U_3O_8 and 48 ppm Th. The resource was calculated at a cut-off grade of 1% REO. In other parts of the deposit historic sample analyses recorded in open file report A16613 in the Geological Survey of Western Australia WAMEX database averaged about 500 ppm Th in the top 48 m of weathered zone in one drill hole. Thorium-rich zones of 200-400 ppm Th were intersected in two drill holes in fresh carbonatite and carbonated magnetite amphibolite to depths of 400 m.

Hastings Rare Metals Ltd: The Yangibana ferrocarnatite-magnetite-rare earth element bearing dykes in WA (termed ironstones) crop out over an area of 500 square kilometres and form part of the Gifford Creek Complex. The dykes are part of a carbonatitic episode which intrudes the Proterozoic Bangemall Group. The ferrocarnatite-magnetite-rare earth element bearing dykes occur as lenses and pods and are typically the last stage of carbonatite fractionation and are enriched in rare earth elements, fluorite and uranium-thorium mineralisation. The Yangibana prospect has a historic (1989) recorded resource of 3.5 Mt at 1.7% REO. The rare earths are in coarse grained monazite containing up to 20% Nd_2O_3 and 1600 ppm Eu_2O_3 . Whole rock chemical analyses of 21 ironstone samples collected from five prospects in the Yangibana area recorded more than 1000 ppm Th for 10 of the samples (1062 ppm to 5230 ppm Th).

Exploration

There has been no widespread exploration for thorium in Australia. However, thorium is a significant component of some deposits being explored for in other commodities. Thorium is present in the Nolans Bore deposit in the NT and in the Toongi intrusives complex in NSW. In April 2011, Centius Gold reported low-altitude airborne thorium and uranium anomalies over the northern rim of its Bethungra Caldera prospect, which was claimed to resemble similar airborne radiometric anomalies over Alkane's Dubbo (Toongi) zirconium-rare earth project to the north. Drilling by Chinalco Yunnan Copper Resources Ltd at the Elaine deposit copper-cobalt-gold south of Mary Kathleen deposit in Queensland has intersected up to 827 ppm ThO₂⁶⁹.

Production

There is no production of thorium in Australia, but it is present in monazite being mined with other minerals in heavy mineral beach sand deposits.

Between 1952 and 1995, Australia exported 265 kilotonnes (kt) of monazite with a real export value of \$284 million in 2008 dollars (Australian Bureau of Statistics 2009)⁷⁰. Most of the monazite was exported to France for extraction of rare earth elements, but the monazite plant in France was closed because its operators were unable to obtain a permit for the toxic and radioactive disposal site.

In current heavy mineral sand operations, the monazite fraction is returned to mine site and dispersed to reduce radiation as stipulated in mining conditions. However, in June 2012, Astron Corporation Ltd indicated in an investor presentation that it intends to export 10 000 tonnes of monazite per year to China from its Donald heavy mineral sand deposit. Astron also reported on 18 June that its zircon product from the Donald deposit contains about 1000 ppm U+Th which they intend to export to China where it will be leached to bring the U+Th content down to 500 ppm raising the possibility that this process could lead to some uranium and thorium by-product⁷¹.

World Ranking

In 2012, the Organisation for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) revised estimates of thorium resources on a country-by-country basis. The OECD/NEA report notes that the estimates are subjective as a result of the variability in the quality of the data, much of which is old and incomplete. Table 15 has been derived by Geoscience Australia from information presented in the OECD/NEA analysis.

OECD/NEA & IAEA (2012) have grouped thorium resources according to four main types of deposits as shown in Table 16. Thorium resources worldwide appear to be moderately concentrated in the carbonatite type deposits, accounting for about 30% of the total. The remaining thorium resources are more evenly spread across the other three deposit types in decreasing order of abundance in the placers, vein-type deposits and alkaline rocks. In Australia, a larger proportion of resources are located in placers where the heavy mineral sand deposits account for about 70% of the known thorium resources.

69 Chinalco Yunnan Copper Resources Ltd, 2012. Quarterly Report for the three months ending 30 June 2012, 14pp.

70 ABS, 2009. International trade, Cat. No.5465.0, Canberra.

71 Astron Corporation Ltd, 2012. Donald mineral sands project – review of uranium/thorium wash process and proved ore reserve update.

Table 15. Estimated thorium resources by region and country.

Region	Country	Identified Thorium Resources (In situ)* (‘000 tonnes)	Total thorium for regions and the world (‘000 tonnes)
Australia	Australia	532	
Australia	Subtotal		532
Americas	Brazil	606 - 1300	
Americas	United States of America	434	
Americas	Venezuela	300	
Americas	Canada	172	
Americas	Others	24.3	
Americas	Subtotal		1536.3 - 2230.3
Europe	Turkey	744-880	
Europe	Norway	320	
Europe	Greenland	86-93	
Europe	Others	166	
Europe	Subtotal		1316 - 1459
Asia	Commonwealth of Independent States (excluding Russian Federation European part but includes the CIS countries below)	1500	
Asia	- Kazakhstan	>50	
Asia	- Russian Federation Asian part	>100	
Asia	- Uzbekistan	5-10	
Asia	India	846	
Asia	China	>100	
Asia	Chinese Taipei	9	
Asia	Iran	30	
Asia	Others	58.5 - 66.5	
Asia	Subtotal		2543.5 - 2551.5
Africa	Egypt	380	
Africa	South Africa	148	
Africa	Morocco	30	
Africa	Nigeria	29	
Africa	Madagascar	22	
Africa	Others	40.5 - 50.5	
Africa	Subtotal		649.5 - 659.5
World	TOTAL		6577.3 - 7432.3

*Sources: Data for Australia compiled by Geoscience Australia; estimates for all other countries modified after OECD/NEA & IAEA, 2012: Resources, Production and Demand. OECD Nuclear Energy Agency & International Atomic Energy Agency.

Table 16. In situ world and Australian thorium resources according to deposit type (modified after OECD/NEA and IAEA, 2012) with Australia's recoverable resources listed in the last column after an overall reduction of 10% for mining and milling losses.

Major deposit type	World Th Resources ('000 tonnes)	World Th Resources (%)	Australian Th Resources ('000 tonnes)	Australian Th Resources (%)	Recoverable Australian Th Resources ('000 tonnes)
Carbonatite	1900	31.3	26.5	5.0	24
Placer deposits	1500	24.7	371	69.7	334
Vein-type deposits	1300	21.4	81.5	15.3	73
Alkaline rocks	1120	18.4	51	9.6	46
Other	258	4.2	2	0.4	2
Total	6078	100.0	532	100.0	479

Tin

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Tin (Sn) is used in solders for joining metals and pipes, as a coating for steel cans and in metal alloys. The largest single application for tin is in solders, which accounts for about half of current world consumption. Solders are used in light engineering applications such as plumbing and sheet metal work, in the motor vehicle industry and in cans for various uses. Another major application for tin is coating steel sheet in the manufacture of tinplate, which accounts for about 16% of world tin consumption. Tinplate is used for containers in the form of tin cans for food products, drinks, oils, paints, disinfectants and chemicals.

Resources

Australia's Economic Demonstrated Resources (EDR) of tin was 243 kilotonnes (kt) at December 2011, up slightly from 229 kt⁷² in 2010. Increases in Australia's EDR were reported at Renison Bell and Queen Hill deposits in Tasmania (Tas) and Baal Gammon in north Queensland (Qld).

Just under 80% of Australia's EDR of tin are contained in the Renison Bell deposit in western Tas. Others include the Mount Lindsay and Queen Hill deposits in western Tas as well as several northern Qld occurrences: the Gillian and associated deposits, and the Mount Garnet and Baal Gammon deposits.

In 2011, Subeconomic Demonstrated Resources (comprising Paramarginal and Submarginal Resources) increased to 97 kt largely because of reclassification of existing resources. Inferred Resources increased from 222 kt in 2010 to 231 kt in 2011. Tasmania accounts for 53% of Inferred Resources, followed by Qld with 24%, and New South Wales (NSW) with 16%.

Accessible EDR

All of Australia's EDR for tin are accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total tin in Proved and Probable Ore Reserves as defined in the JORC Code. In 2011, JORC Code reserves of 119 kt accounted for about 49% of Accessible Economic Demonstrated Resources (AEDR). This compares with 126 kt of JORC Code reserves in 2010.

Exploration

Exploration continued in the historic tin mining areas of Herberton-Mount Garnet in north Qld, in the New England, Bourke and Broken Hill regions of NSW and in western Tas. Data on tin exploration expenditures are not reported by the Australian Bureau of Statistics.

Production

Australia's mine production in 2011 was just over 5000⁷³ tonnes of tin in concentrates, a decrease from the 2010 production of 6600 tonnes. There has been no production of refined tin in Australia since 2007 when the Greenbushes tin smelter in Western Australia (WA) closed. Total exports of tin for 2011 were 4992 tonnes valued at \$119 million⁷⁴. This compares with 6011 tonnes valued at \$116 million exported in 2010.

72 The EDR for 2010 has been reassessed as 229 kt, from the previously reported value 358kt. This was due to the reclassification of older resource figures as subeconomic in several deposits, and a correction of figures within one deposit.

73 Figures do not include tin production in Western Australia for which data is not available. Production in that state is not believed to be significant.

74 Export statistics from Resources and Energy Quarterly publications of the Bureau of Resources and Energy Economics, Department of Resources, Energy and Tourism.

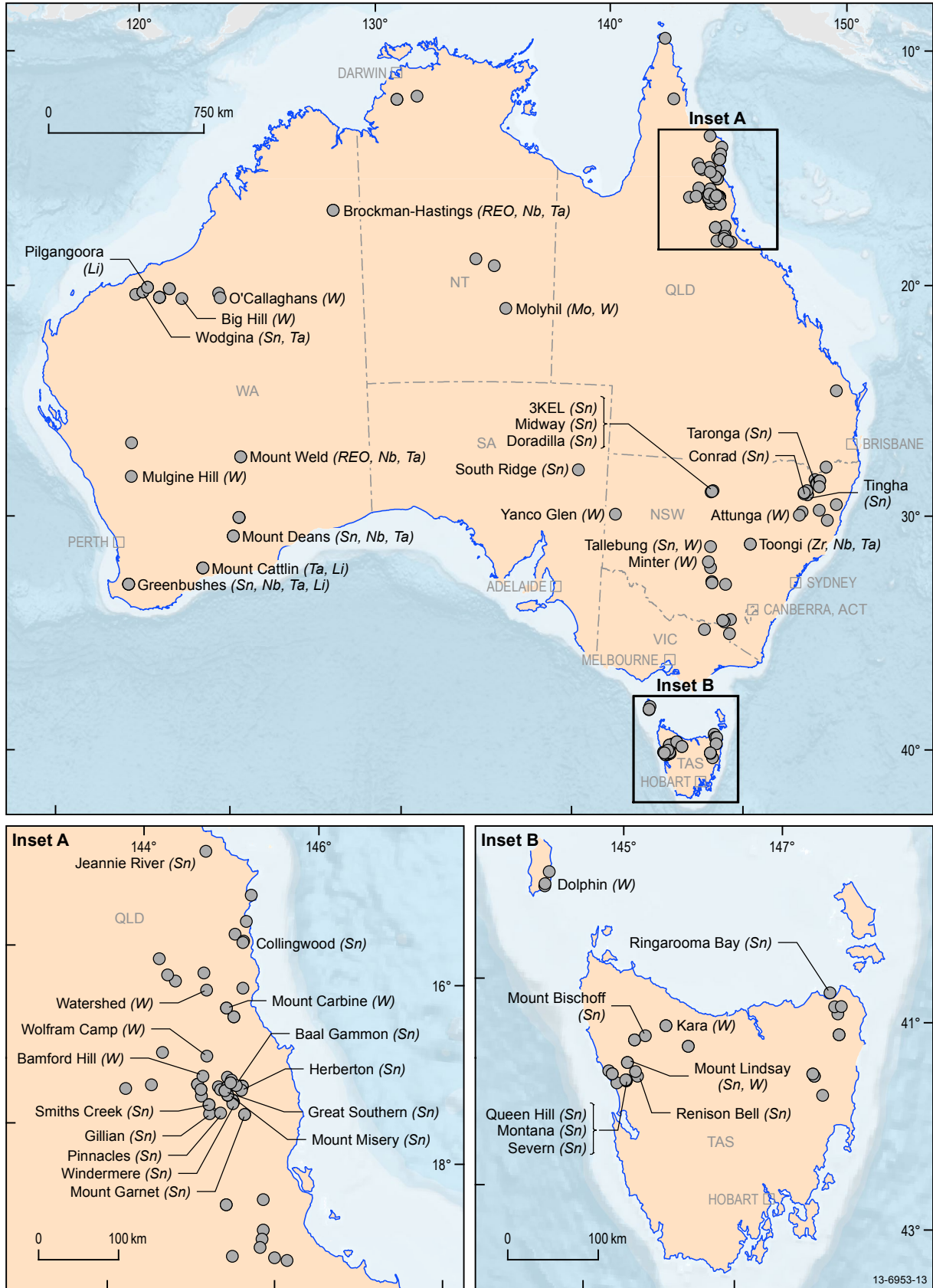


Figure 14. Map showing location of tin (Sn), tungsten (W), tantalum (Ta), niobium (Nb), rare earth oxides (REO) and lithium (Li) deposits and prospects discussed in commodity chapters.

World Ranking

World economic resources of tin in 2011 are estimated to be 4863 kt based on United States Geological Survey (USGS) data and updated by Geoscience Australia for Australia's resources. According to the USGS, China holds about 31% of the resources followed by Indonesia with about 16% and Brazil with about 12%. Based on the USGS figures and those updated by Geoscience Australia, Australia has a 5% share of world resources of tin.

World production of tin in 2011 is estimated to be 250 kt based on USGS data updated with Australia's production data. These figures represent a slight decrease on production of 265 kt of tin in 2010. China was the major producer with about 44% of world production, followed by Indonesia with about 20% and Peru with about 14%. USA production was not recorded for confidential reasons. Australian production of tin was ranked number seven in the world.

Industry Developments

The price of tin on the London Metal Exchange had recovered significantly from the late-2008/early-2009 low point experienced during the global financial crisis (US\$10 000 a tonne or \$14 400), reaching highs (US\$33 000 or around \$33 000) in the second half of the 2010-11 financial year. The price has subsequently receded, dropping to below US\$18 000 in August 2012 before recovering slightly to about US\$22 000 in early October 2012.

In March 2010, Metals X Limited (Metals X) completed the sale of a 50% interest in its Tasmanian Tin assets to the world's largest tin producer, China's Yunnan Tin-Parksong Group (YTPG). The Tasmanian Tin assets include the **Renison Bell** Mine, the Renison Tin Concentrator, the Renison Expansion Project, **Rentails**, and the **Mount Bischoff** Tin Project. A new joint venture company, Bluestone Mines Tasmania Joint Venture Pty Ltd (BMTJV), was established by Metals X through its wholly owned subsidiary Bluestone Mines Tasmania Pty Ltd and Yunnan Tin Parksong Australia Holding Pty Ltd and will manage the assets.

BMTJV current operations are at the **Renison Bell** underground mine near Zeehan in western Tas. Production is from both the South Renison and higher grade North Renison areas with production from North Renison beginning in mid 2012. Ore from the mine is treated at the Renison concentrator. Production for 2011 was 5014 tonnes of tin metal and 417 tonnes of copper metal. With mining from both North and South Renison, production is expected to reach 8000 tonnes of tin in concentrates a year. A copper circuit was commissioned in December 2010, with production of around 500 tonnes a year of copper in concentrate. Mining ceased at **Mount Bischoff** in July 2010 and the last ore was treated in late 2010.

The company is carrying out both underground and surface exploration around the Renison deposit. Highlights from underground include favourable extensions to the Lower Federal, Huon and Northern King ore zones, as well as delineation and further definition of the Central Federal-Bassett zone, a newly discovered mineralised zone in the area between the southern and northern declines access. Surface exploration is focussing on the Sligo ore body as well as the Dalcoath and Federal areas, which the company suggests will be exploitable by open-pit mining. Resources at Renison Bell to 31 March 2012 comprised Measured Resources of 972 kt at 2.0% Sn, Indicated Resources of 5457 kt at 1.46% Sn, and Inferred Resources of 3256 kt at 1.67% Sn, representing about 153 500 tonnes of contained Sn. The resource includes Proved Reserves of 372 kt at 1.44% Sn and Probable Reserves of 2970 kt at 1.36% Sn.

In 2009, Metals X completed a feasibility study on proposals to recover tin from tailings produced by historic processing of tin ores from Rentails at Renison Bell mine. Resources at Rentails to 31 March 2012 comprise Measured Resources of 19 999 kt averaging 0.45% Sn and 0.21% copper (Cu), which represents 89 400 tonnes of contained Sn and 42 400 tonnes of contained Cu. The resource includes Probable Reserves of 19 158 kt at 0.45% Sn and 0.21% Cu. The recovery project proposes reclaiming tailings at a rate of 2 Mt a year to produce about 5300 tonnes Sn and 2000 tonnes Cu contained in concentrates per year. The company reported that a combination of sulphide flotation and tin flotation techniques would produce a 10% tin concentrate which could be smelted to produce a tin fume product assaying in excess of 68% tin.

Metals X's **Collingwood** mine, about 30 km south of Cooktown in north Qld, has been under care and maintenance since its closure in mid 2008. The company has decided to dispose of the property.

Following completion of a successful prefeasibility study in March, 2011, Venture Minerals Limited (Venture) commenced a bankable feasibility study for its **Mount Lindsay** tin-tungsten deposit located 15 kilometres (km) northwest of Renison Bell tin mine and 20 km west of Rosebery in western Tas. The prospect is in magnetite-rich (Fe₃O₄) skarns within the contact

aureole of the Meredith granite, which is part of a suite of Devonian granites that are the source rocks for a number of large tin, tungsten and magnetite deposits in western Tas and on King Island in Bass Strait.

The Mount **Lindsay** tin-tungsten deposit has combined resources of 43 million tonnes (Mt) at 0.4% Sn equivalent (with a 0.2% cut-off) or 10 Mt at 0.7% Sn equivalent (at 0.45% cut-off). The latter figure includes Indicated Resources of 6.2 Mt at 0.4% Sn and 0.3% tungsten oxide (WO₃). The deposit also includes an iron (Fe) resource. The bankable feasibility study is expected to be completed in the second half of 2012.

Venture completed drilling associated with the feasibility study in late 2011 and highlights included 48 metres (m) at 0.8%, 30 m at 0.9% and 68 m at 0.6% Sn equivalent at the No. 2 skarn, and 22 m at 1.7%, 12 m at 2.0% and 22 m at 1.2% Sn equivalent at the main skarn. The company also completed a pilot scale metallurgical program in August 2012 that demonstrated recoveries of 72% Sn and 83% WO₃, as well as high grade tungsten concentrate (more than 66% WO₃). Venture submitted a mining lease application for the company's Mount Lindsay tin-tungsten project on 15 September 2011.

In August 2012, Venture announced favourable drill intersections from its first hole into the **Big Wilson** Project approximately 6 km northeast of the Mount Lindsay Project. Intersections include 35.4 m at 1.0% Sn, including 17.4 m at 2.0% Sn and 4.0 m at 5.6% Sn. The Big Wilson Prospect occurs in an area of historic alluvial tin workings with mineralisation including both skarn and greisen styles.

In January 2012, Stellar Resources Limited (Stellar) took over control of the **Heemskirk** Tin Project through acquisition of joint venture partner Gippsland Limited's 40% share of the project. The Heemskirk project, which comprises the **Queen Hill**, **Montana** and **Severn** deposits, has a combined mineral resource of 4.4 Mt at 1.1% Sn (at March 2011), including Indicated Resources of 1.6 Mt at 1.2% Sn at the Queen Hill deposit.

Stellar completed a favourable scoping study for the three deposits in July 2011 which indicated the potential for an economic underground tin mine recovering 600 kt of ore per annum over 7.6 years and producing about 3900 tonnes per annum (tpa) of concentrates. The company is undertaking a prefeasibility study which includes detailed deposit drilling in 2012 (10 000 m planned) to upgrade and expand the Severn, Queen Hill and Montana resources. The initial results of this drilling show that mineralisation in the Severn deposit occurs within multiple tin lodes in a broad iron sulphide stockwork envelope. Favourable intercepts include 42 m at 1.11% Sn, including 12 m at 2.58% Sn. Further metallurgical test work is underway.

In February and September 2011, TNT Mines Limited applied for offshore exploration tenements in Ringarooma Bay as part of its **Ringarooma Bay** alluvial tin project in northeast Tas. The tenements cover parts of the old Ringarooma River channel. The project has an historic Indicated Resource of 16 million cubic meters at 227 grams of tin per cubic meter. The company is planning to undertake a geophysical survey as well as sampling of the seafloor mineralisation. TNT has undertaken work at its other Tas properties, including initial metallurgical investigations at the undeveloped Moina fluorspar-tin-tungsten deposit which is a magnetite skarn with complex metallurgy in northwest Tas.

In the third quarter of 2011, mining activities commenced at the Monto Mineral Limited (Monto) **Baal Gammon** polymetallic deposit, 7 km west of Herberton in north Qld. Mining was being undertaken by Kagara Limited (Kagara) which has a Minerals Rights Agreement with Monto. The ore was being processed at Kagara's Mount Garnet copper processing facility and just under 38 kt of ore with an average grade of 1.9% Cu and 41.5 g/t silver (Ag) had been milled prior to suspension of activities by Kagara in April 2012 and before the company went into voluntary administration. In September 2012, Monto announced the recommencement of mining activities by Kagara (administrators appointed) at the Baal Gammon mine with the first stage of mining to develop the open pit to a level sufficient to contain storm water flows resulting from previous flooding.

Prior to cessation of mining, Kagara undertook resource diamond drilling at the deposit and released an updated resource estimate with Indicated Resources of 2769 kt at 1.0% Cu, 40 g/t Ag, 0.2% Sn and 38 g/t indium (In). Tin was not being extracted but Monto and Kagara were assessing the technical and commercial feasibility of a tin extraction circuit.

In November 2011, Monto applied successfully for a mining lease over the **Confederation** copper-tin prospect, contiguous with the existing Baal Gammon Mining Leases and within 800 m of the Baal Gammon mine. Monto undertook drilling at the Confederation prospect in the first half of 2012. Intercepts included 6 m at 4.33% Cu, 1.25% Sn, 106 g/t Ag and 301 g/t In.

In July 2011, Consolidated Tin Mines Ltd (Consolidated) completed 8148 m of drilling in the Mount Garnet Project area 200 km southwest of Cairns in Qld at the **Gillian** (5 km southwest of Mount Garnet), and **Windemere** (25 km northeast of Mount Garnet) tin deposits, and prospects in the **Coolgarra** area (15 km northeast of Mount Garnet). Results for

the Windemere deposit include intersections of 2 m at 2.7% Sn, 4 m at 1.16% Sn, and 15 m at 0.63% Sn. Results for Gillian included 23 m at 1.4% Sn and 28.5 m at 0.93% Sn, plus the identification of zones of copper (Cu) mineralisation, including 11 m at 0.93% Cu.

Further drilling was undertaken at the Gillian and **Pinnacles** deposits in late 2011 and the second quarter of 2012. Initial results from this drilling for Gillian were positive resulting in significant near surface intersections, including 29 m at 1.24% Sn and 27 m at 1.01% Sn. Favourable intersections were reported also for the Pinnacles project area with grades between 0.4 and 0.86% Sn. Drilling confirmed that the mineralisation at **Sniksa**, **Hartog** and **Llahsram** in the Pinnacles deposit are all part of the same flat-lying mineralised skarn.

In September 2010, Consolidated announced a revised total JORC Code resource of 7.38 Mt at 0.6% Sn, 5.27 Mt at 25.78% Fe and 0.96 Mt at 15.25% fluorine (F) for its Mount Garnet project, reflecting the inclusion of resources at the Windemere deposit. Included within the total resource, is a JORC Code Measured Resource at the Gillian deposit of 1.2 Mt at 0.82% Sn. The Gillian, Pinnacles and Windemere deposits are in iron-rich skarns adjacent to granitic intrusions, while the Coolgarra area contains sediment-hosted and granite greisen mineralisation. The Mount Garnet skarn deposits contain fine cassiterite which is difficult because of metallurgical problems. Through 2011-12 Consolidated continued metallurgical testing to separate the fine cassiterite from the ironstone skarn material.

It also processed an 80 tonne sample from the Gillian Project at the Talison mine site at Greenbushes in WA. The company is also evaluating by-product Fe, F, Cu and zinc (Zn).

Consolidated initiated a prefeasibility study at the Mount Garnet Project, which the company indicated should be completed by the end of 2012 and would incorporate results from the metallurgical test work. In May 2012, Consolidated announced it had entered into agreement (approved by shareholders in July 2012) with major shareholder Snow Peak International Pty Ltd (Snow Peak) to fund the completion of the prefeasibility study, which, on completion, gives Snow Peak the option to earn up to 50% interest in a joint venture with Consolidated to develop the Mount Garnet project. The company also announced, in October 2011, that it had reached agreement with Friends Exploration Pty Ltd to purchase the **Jeannie River** prospect, 92 km northwest of Cooktown in north Qld. On the basis of previous exploration results by Carpentaria Exploration Company, Consolidated announced a JORC Code compliant Inferred Resource of 2240 kt at 0.60% Sn. The Jeannie River prospect comprises parallel cassiterite mineralised quartz veins.

In 2011-12, Monto Mineral Limited (Monto) continued exploration at its **Herberton** tin project 70 km southwest of Cairns in north Qld. The work included detailed stream-sediment and geochemical sampling in the region as well as rock-chip sampling traverses over the **Pompeii**, **Arbouin** and **Kitchener** tin targets. In late 2011, Monto signed two option agreements to purchase several advanced tin mining properties adjacent to its own tenements, including Mining and Exploration leases incorporating the historic **Great Southern** tin mine and the **Mount Misery** prospect centred on the former Mount Tin mine. The Mount Misery prospect was extensively explored by Western Mining Corporation in the 1980s which identified a non-JORC Code compliant resource of between 100 and 140 kt of mineable ore at a grade of 0.4% to 0.6% Sn to a depth of 100 m, with a cut-off grade of 0.2% Sn. The Great Southern area was also the subject of detailed exploration in the mid-1960s by Metals Exploration NL generating non-JORC Code compliant target mineralisation of 25 to 30 kt at a grade of 1 to 1.3% Sn.

MGT Mining Limited (formerly Xtreme Resources Limited and now a 81% owned subsidiary of MGT Resources) continued exploration around the historic tin mines in the immediate proximity of its Mount Veteran tin plant, including the **Dalcouth**, **Summer Hill**, **Extended**, **Tom Hood** and **Smiths Creek mines**. All are located in the Mount Garnet district, north Qld. An upgrade of the tin plant was completed in 2011 resulting in a 70 000 tpa processing capacity. A stage 2 upgrade to 250 000 tpa processing capacity is being planned. A mining lease was granted in late 2011 from which tailings and ore will be used as feed for the mill. An application for another mining lease is in process.

At **Greenbushes** mine, in southwest WA, production of tin ceased in 2007 with the closure of the smelter. Tin resources for Greenbushes operations have not been publicly reported for more than a decade. Historical estimates of tin resources for Greenbushes have not been included in Australia's EDR since 2008. Global Advanced Metals (GAM) indicates that it has produced by-product tin from its tantalum deposit at Wodgina about 100 km southeast of Port Hedland, although amounts are not reported. Production at Wodgina resumed in April 2011 with ore processed at GAM's Greenbushes facilities. Wodgina closed again early 2012 following softening of demand for tantalum.

In 2011-12, Malachite Resources (Malachite) shifted focus, concentrating on its Lorena gold project in northwest Qld. As a result, tin exploration by the company was minor with rock-chip and stream-sediment sampling in the **Tingha** Project,

northern NSW. Malachite entered into an option to purchase agreement with Elsmore Resources Ltd, which Elsmore exercised in November 2011 for Malachite's **Elsmore** Project, 18 km east-southeast of Inverell in northern NSW.

Malachite continued work on its **Conrad** Project 25 km south of Inverell in northeast NSW investigating polymetallic silver deposits, which also contain tin (as stannite and cassiterite). The current global resource figures for Conrad have Indicated Resources of 447 kt at 123.8 grams per tonne (g/t) Ag, 0.26% Cu, 1.3% lead (Pb), 0.46% Zn, 0.28% Sn and 7.7 g/t In as well as Inferred Resources of 1807 kt at 101.9 g/t Ag, 0.21% Cu, 1.22% Pb, 0.46% Zn, 0.22% Sn and 6.4 g/t In.

A preliminary scoping study into the Conrad deposit highlighted the narrow width of ore zones (largely 0.6 to 0.8 m) and the sensitivity of such to the economics of the deposit. In 2012, Malachite granted an exclusive six-month option to a privately-owned Australian mining contractor with narrow vein expertise and vertical mining technology, Mancala Resources Pty Ltd, to carry out an evaluation of the Conrad Silver Project and the right (if exercised) to take a 50% interest in the project by funding and completing a feasibility study.

YTC Resources Limited (YTC) has the right to earn 70% of the **Doradilla** Project from Templar Resources, a wholly owned subsidiary of Straits Resources Ltd, by spending \$1.5 million over five years. The **Doradilla** project, 55 km southeast of Bourke NSW, contains the Doradilla-Midway-3KEL tin deposits, which occur within a linear skarn unit that can be traced for more than 17 km along strike. The resource is limited to the weathered zone (laterite) where tin is hosted in stanniferous goethite, garnets, secondary cassiterite and minor primary cassiterite. The company has announced a combined Inferred Resource for the tin laterite (oxide) mineralisation of 7.81 Mt averaging 0.28% Sn (at a cut-off grade of 0.1% Sn) for 22.3 kt of contained tin. During 2011, YTC undertook drilling to test the mineralised contact of an intrusion associated with copper-tungsten mineralisation at the historic **Doradilla Mine**. The company reported broad intervals of anomalous lead and zinc and occasional intervals of anomalous copper, tin and silver. There appears to have been limited activity since then.

At its **Tallebung** tin-tungsten deposit, 70 km northwest of Condobolin in central NSW, YTC has commenced a Right to Negotiate Process under the Native Title Act to seek access to undertake two deep drill holes aimed at testing targets from a previous resistivity survey (below outcropping mineralisation) and to assist in scoping of the Tallebung system for a potential large-tonnage, low-grade tin deposit. In the September quarter of 2011, YTC completed a shares and options agreement with Taronga Mines Limited and Australian Oriental Mines for its New England tin projects of **Pound Flat** and **Torrington**. Taronga Mines also controls the adjacent lease over the large, low grade **Taronga** tin deposit.

In 2011-12, Thomson Resources (Thomson) undertook exploratory drilling of magnetic targets at four prospects at the **Cuttaburra** and **Falcon** projects, which were spread over a 40 km east-west zone within the southern part of the undercover Thomson Orogen in northwest NSW. Thomson reported that drilling on the four prospects intersected evidence of mineralised hydrothermal systems, including alteration and mineralisation. Two of the targets gave high grade polymetallic intercepts, particularly gold to 3.7 g/t and silver to 113 g/t, but also bismuth to 0.4%, Cu to 0.5%, Pb to 1.8%, Sn to 0.8%, W to 0.6% and Zn to 4.25%. Mineralisation is reported to be occurring as sheeted and stockwork veins up to a metre in width and within wide zones of altered basement rocks of the Thomson Orogen. On the basis of the polymetallic assemblage, plus the presence of granite intersected in one hole, the company is suggesting an intrusion-related gold style of mineralisation. Thomson has planned additional drilling to test shallower parts of the mineralisation.

Further exploration at the **Prospect Hill** Tin Project, in the northern Flinders Ranges, South Australia, has been postponed indefinitely because of matters associated with Native Title. Havilah Resources, which has earned a 65% interest in the project, had planned further exploration in 2011-12, including drilling aimed at increasing the hard rock resource. The **South Ridge** prospect, within the Prospect Hill project area, has old Inferred Resources of 172 000 tonnes at 1.15% Sn.

Tungsten

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Tungsten (W) metal, and its alloys, are amongst the hardest of all metals and has the highest melting point of all pure metals. The combination of its hardness and high temperature capabilities make it desirable for many commercial and industrial applications. Tungsten's range of properties also makes it difficult to substitute with other metals. It occurs as wolframite, which is an iron-manganese tungstate mineral ((Fe,Mn)WO₄), and scheelite (CaWO₄). The major use for tungsten is within cemented carbides, also called hard metals. Tungsten carbide has a hardness approaching that of diamond and is used for cutting and in wear-resistant materials, primarily in the metalworking, mining, oil drilling and construction industries. Tungsten alloys are used also in electrodes, filaments (light bulbs), wires and components for electrical, heating, lighting and welding applications. Tungsten is used also in chemical applications, including as catalysts, as well as pigments for paints. Ferrotungsten (FeW) is a high value-added intermediate product and is used in steels and alloys where hardness and heat resistance are required. Tungsten is commonly supplied as mineral concentrates typically with 65% or more contained tungsten trioxide (WO₃). A number of secondary tungsten compounds are also important. These include ammonium paratungstate (APT), tungsten trioxide (WO₃), ferrotungsten (FeW) and tungsten carbide (WC), as well as tungsten metal.

Resources

Australia's total Economic Demonstrated Resources (EDR) of tungsten at December 2011 were 376 kilotonnes (kt), similar to resources in 2010 (367 kt⁷⁵). Australia's EDR are in deposits at Dolphin and Bold Head on King Island in Bass Strait off Tasmania (Tas), Kara and Mount Lindsay in Tas, at Watershed in Queensland (Qld), O'Callaghans, Big Hill and Mount Mulgine in Western Australia (WA) and Molyhil in the Northern Territory (NT). The majority of Australia's EDR of tungsten are within WA (about 61%), with most of this at the O'Callaghans deposit (about 50%), while Tas has 22% and Qld 14%.

In 2011, Subeconomic Demonstrated Resources (comprising Paramarginal and Submarginal Resources) were 12 kt, which is equivalent to 3% of the total Demonstrated Resources. Meanwhile, Inferred Resources decreased slightly from 110 kt in 2010 to 107 kt in 2011. Queensland accounts for 47% of Inferred Resources, followed by WA with 32%, Tas with 11% and New South Wales (NSW) with 9%.

For location of tungsten deposits refer to Fig. 14 in the Tin chapter.

Accessible EDR

All of Australia's EDR for tungsten are unencumbered.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total tungsten in Proved and Probable Ore Reserves as defined in the JORC Code. In 2011, JORC Code reserves of 182 kt accounted for approximately 48% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

Exploration in 2011-12 was largely within more advanced projects with the emphasis on feasibility studies. These projects are briefly discussed under Industry Developments below. Data on exploration expenditure for tungsten are not reported by the Australian Bureau of Statistics.

Production

During 2011, 27 tonnes of high-grade scheelite concentrates averaging 72% WO₃ together with magnetite was produced at the **Kara** scheelite mine near Hampshire in northwest Tas, representing 15.4 tonnes of contained tungsten. The scheelite and magnetite were produced from skarn within Ordovician limestone adjacent to the contact with Devonian granite. Initial production of wolframite concentrates commenced at both **Wolfram Camp** and **Mount Carbine** in north Qld in 2012.

75 Reassessed as 367 kt, down from the previously reported 403 kt.

World Ranking

In 2011, world economic resources of tungsten were estimated to be around 3300 kt based on the United States Geological Survey (USGS) data and updated by Geoscience Australia for Australia's resources. According to the USGS, China holds approximately 58% of tungsten resources followed by Russia with 7.6% and the USA with 4.2%. Based on the USGS figures and those updated by Geoscience Australia, Australia has an 11.4% share of world resources of tungsten.

The USGS estimates that world production of tungsten in 2011 amounted to 72 kt compared with 69 kt⁷⁶ in 2010. China was the major producer with approximately 83%, followed by Russia with 4.3%. USA production was not recorded for confidential reasons. Over the past few years, the Chinese Government has restricted the amount of its tungsten ores that can be offered on the world market by applying export quotas and taxes, favouring instead the export of value-added downstream tungsten materials and products.

Industry Developments

The price of tungsten rose dramatically following the global financial crisis from a low of less than US\$200 per metric tonne unit (MTU = 10 kilograms) of ammonium paratungstate (APT) in late 2008 to mid 2009 to reach new highs of US\$480/MTU in mid 2011. This price increase reflected growth in demand and tightening of supply by China. Prices have eased since to around US\$400/MTU in mid-2012, but are still above 2000-10 long term average levels. There has been continued activity at a number of projects, including initial production at both Wolfram Camp and Mount Carbine in north Qld.

In 2011, Metallic Minerals Limited completed its sale of the wholly owned subsidiary, Wolfram Camp Mining Pty Ltd, to the German mining company, Deutsche Rohstoff AG (DRAG), which has given DRAG an 85% stake in the **Wolfram Camp** tungsten-molybdenum project, 90 kilometres (km) west of Cairns in Qld. In November 2011, DRAG announced it had acquired Tropical Metals Pty Ltd which held the remaining 15% of the Wolfram Camp Mine project, as well as 100% of the **Bamford Hill** deposit 25 km south of Wolfram Camp, giving DRAG full control over both deposits.

In February 2012, DRAG delivered its first WO₃ concentrate from Wolfram Camp. In June 2012, daily production was reported to be about 1.5 tonnes of concentrates a day which was worth about \$1 million a month. The Wolfram Camp mine was officially reopened in July 2012 and the company is expecting commercial production from July 2012. The company also announced a planned exploration program at both Wolfram Camp and Bamford Hill and indicated it was targeting a JORC Code compliant resource estimate for Bamford Hill. The most current resource estimate for Wolfram Camp, which was released by Planet Metals Limited in May 2010, is 1.42 million tonnes (Mt) grading 0.6% WO₃ and 0.12% molybdenum (Mo) comprising 0.78 Mt at 0.56% WO₃ and 0.13% Mo in Indicated Resources and 0.64 Mt grading 0.65% WO₃ and 0.11% Mo in Inferred Resources.

Vital Metals Limited's wholly owned **Watershed** scheelite project 150 km northwest of Cairns in Qld at 30 June 2012 has a Measured Resource of 4.42 Mt at 0.25% WO₃, an Indicated Resource of 11.51 Mt at an average grade of 0.24% WO₃, in addition to an Inferred Resource of 4.73 Mt at 0.26% WO₃, using a cut-off grade of 0.10% WO₃, for 50 700 tonnes of contained WO₃. In mid-2011, Vital announced it had entered an earn-in agreement with Japan Oil, Gas and Metals National Corporation (JOGMEC) for 30% of the Watershed project by co-funding a definitive feasibility study (DFS) for the project. The DFS is scheduled for completion in late 2012. Once completed the JOGMEC interest will pass to a Japanese-owned corporation which, in partnership with Vital, will take the project into development and operation. Vital predicts construction will begin in 2013 with concentrate being produced in 2014.

Carbine Tungsten Ltd (formerly Icon Resources Limited) has completed construction and opened its tailings re-treatment plant at the **Mount Carbine** project in March 2012 with the first shipment of 1134 MTU of WO₃ concentrate in late June 2012. The company announced that the grade of concentrate produced greatly exceeded expectations from the tailings-recovery feasibility study. The company is hoping for final production of 5000 MTU a month from the re-treatment plant with an envisaged project life of around two years. The tailing dams are estimated to comprise approximately 2 Mt at 0.1% WO₃. In September 2012, Carbine Tungsten released an Indicated Resource of 12 Mt at 0.07% WO₃ for the low-grade stockpile. The company reports a production target of 15 000 MTU of WO₃ in concentrate a month from the low-grade stockpile material. This target assumes a processing rate of 3 million tonnes per year

76 Reassessed as 69 kt up from the previously reported 61 kt.

(Mtpa) to the X-ray sorter and a milling rate of X-ray sorter accept of about 300 000 tonnes a year. Based on both test work and results from the tailings re-treatment plant, the company expects a recovery rate of 80% WO₃.

Carbine Tungsten has completed a favourable feasibility study investigating the economic viability of re-establishing the Mount Carbine tungsten mine. The study considered both an open-cut, hard-rock resource and processing of previously stockpiled low-grade material, which together would provide a 15 year project life. A result of this study was resource upgrades in June and August 2012, with an Indicated Mineral Resource of 18.1 Mt at 0.14% WO₃ and an Inferred Resource of 29.3 Mt at 0.12 % WO₃ at a 0.05% WO₃ cut-off for 48 kt of contained tungsten beneath and adjacent to the Mount Carbine open-cut mine which closed in 1987. Carbine Tungsten indicated that it considered the Indicated Resource is also a Probable Reserve based on mining 3 Mtpa and a price of US\$290/MTU at a cut-off of 0.05%. Carbine Tungsten also indicated it intends to begin construction for the hard rock project in early 2013 and is envisaging production from 2014 of 250 000 MTU a year of tungsten concentrate. The company recently completed a program of five deep diamond drill holes testing the extent of the mineralising system at depth and along strike and dip close to the Mount Carbine Mine with some favourable intersections, including 12.37 metres (m) at 0.133% WO₃ from 81 m.

The Dolphin Joint Venture between King Island Scheelite (KIS) and Chinese Hunan Nonferrous Metals Corporation (HNC) to redevelop the former **King Island** scheelite mine on southeast King Island off Tas was terminated in December 2010. HNC transferred its 50% interest in the joint venture assets to KIS's wholly owned subsidiary, Australian Tungsten Pty Ltd (ATPL). HNC has a royalty of 2% on future project revenue from the project, capped at \$3.9 million. KIS has undertaken a DFS investigating both re-treatment of tailings and re-opening the underground mine. Outcomes of the DFS include a planned 10-year mine life from both underground mining and re-treatment of tailings, although it would be 7.5 years if mining was from Dolphin only, producing 3500 tonnes per annum (tpa) of contained WO₃ in concentrate. King Island Scheelite reported in May 2010 Indicated Resources for the Dolphin Mine and Bold Head Mine as 8.42 Mt averaging 0.95% WO₃ and 2.3 Mt averaging 0.73% WO₃, respectively, for a combined total of 96 780 tonnes of contained WO₃ at a cut-off grade of 0.25% WO₃. Estimates of Probable Reserves were upgraded in August 2011 to 2.69 Mt averaging 1.04% WO₃ and containing 27 940 tonnes of WO₃. In June 2011, the company also reported Measured Resources for the tailings at the Dolphin Mine at a cut-off grade of 0.08% WO₃ as being 2.7 Mt averaging 0.17% WO₃, with 459 000 tonnes of contained 4590 tonnes of WO₃.

Following completion of a successful prefeasibility study in March 2011, Venture Minerals Limited (Venture) commenced a bankable feasibility study for its **Mount Lindsay** tin-tungsten (Sn-W) deposit. The Mount Lindsay project is located 15 km northwest of Renison Bell tin mine and 20 km west of Rosebery in western Tas. The prospect is in magnetite-rich (Fe₃O₄) skarns within the contact aureole of the Meredith granite, which is part of a suite of Devonian granites that are the source rocks for a number of large (Sn-W-Fe₃O₄) deposits in western Tas and on King Island in Bass Strait. The **Mount Lindsay** Sn-W deposit has combined resources of 43 Mt at 0.4% Sn equivalent with a 0.2% cut-off or 10 Mt at 0.7% Sn equivalent at 0.45% cut-off. The latter figure includes Indicated Resources of 6.2 Mt at 0.4% Sn and 0.3% WO₃. The deposit also includes an iron resource. The bankable feasibility study is expected to be completed in the second half of 2012. Venture completed drilling associated with the feasibility study in late 2011. Highlights from the drilling included 48 m at 0.8%, 30 m at 0.9% and 68 m at 0.6% Sn equivalent at the No. 2 skarn, and 22 m at 1.7%, 12 m at 2.0% and 22 m at 1.2% Sn equivalent at the Main skarn. The company also completed a pilot-scale metallurgical program in August 2012, which demonstrated recoveries of 72% for Sn and 83% for WO₃ as well as a high-grade tungsten concentrate of more than 66% WO₃. In September 2011, Venture submitted a Mining Lease Application for the company's Mount Lindsay Tin-Tungsten Project.

Frontier Resources Ltd announced in April 2012 that it was divesting its Tasmanian projects and assets into the subsidiary Torque Mining Ltd, with an initial public offering planned for later in 2012. The company continued exploration of its **Moina** Project area, focussing on the stratiform gold and base metal **Narrawa** deposit 40 km southwest of Devonport in Tas and on the gold-bismuth (Au-Bi) **Stormont** skarn deposits 190 km northwest of Hobart, Tas. Exploration in the Moina Project area is targeting mineralisation associated with the Dolcoath Granite, including tungsten and tin. The company previously completed a detailed soil geochemical program over four square kilometres encompassing the Narrawa deposit and identified zones anomalous in tungsten, tin, molybdenum, copper (Cu) and bismuth as well as gold.

In January 2012, Thor Mining PLC (Thor) reported Indicated Resources of 3.8 Mt at 0.29% WO₃ and 0.22% molybdenum disulphide (MoS₂) and Inferred Resources of 0.9 Mt at 0.25% WO₃ and 0.25% MoS₂. Resource figures in April 2012 include open cut Probable Reserves of 1.64 Mt grading 0.42% WO₃ and 0.13% MoS₂ for its **Molyhil**

Tungsten and Molybdenum Project, 250 km northeast of Alice Springs in the NT. Potential development of the project was hampered by the global financial crisis and a decline in international metal prices, which resulted in the company scaling back activities. Thor had signed an off-take agreement with one of China's largest State-owned companies, CITIC Australia Trading Limited, for CITIC to take all of the molybdenum and tungsten concentrates produced from the project but that agreement has since lapsed. The recent increase in tungsten prices has resulted in renewed interest and in mid-2012 Thor completed a positive DFS of the deposit, with a mine life of 4 years based on current reserves.

Hazelwood Resources Limited (Hazelwood) released an initial ore reserve estimate at a cut-off grade of 0.05% WO₃ for the **Big Hill** deposit of Proven Reserves of 18.78 Mt averaging 0.11% WO₃ and Probable Reserves of 6.43 Mt averaging 0.11% WO₃. Using a cut-off grade of 0.05% WO₃, the deposit's Measured Resources are 22.94 Mt averaging 0.11% WO₃, with Indicated Resources of 11.95 Mt grading 0.1% WO₃ and Inferred Resources of 12.54 Mt grading 0.08% WO₃ for a total resource of 47.43 Mt averaging 0.1% WO₃. The deposit is part of the **Cookes Creek** tungsten project located 70 km from Nullagine in WA. Hazelwood is undertaking a definitive feasibility study for the Big Hill deposit, including large-scale metallurgical test work on bulk ore samples, which has demonstrated the ability to produce high-purity tungsten concentrate.

Hazelwood completed an integrated prefeasibility study in 2010 that incorporated its **Big Hill** tungsten deposit and its jointly owned ferrotungsten project in Vietnam. In June 2011, Asia Tungsten Products Company Ltd (ATC), which is 60%-owned by Hazelwood, completed construction of a ferrotungsten plant in the Vihn Bao district near the Port of Haiphong in northern Vietnam. The plant is production-ready and is expected to have a capacity of approximately 3000 tonnes of contained tungsten in the form of 75%-grade ferrotungsten a year. Production is planned to commence in 2013 but progress has been delayed by funding negotiations, which include finance for the plant start-up. Hazelwood has indicated it plans to develop the Big Hill deposit to provide feedstock for the Vietnam ferrotungsten project. The company announced in mid-2012 that a non-binding memorandum of understanding had been agreed for the acquisition by Hazelwood of the remaining 40% of the ATC Ferrotungsten Project, subject to both shareholder and regulatory approval. Hazelwood also announced that a purchase agreement had been reached with a North American-based supplier for up to 54 tonnes of tungsten concentrate a month, which the company indicates will cover up to half of the required feedstock for the first 12 months of operations. Hazelwood indicated that longer-term supply arrangements would be put in place once the smelter reached steady-state operations.

Hazelwood is also evaluating the **Mulgine Hill** and **Trench** deposits of its Mount Mulgine Project which is owned 70% by Hazelwood and 30% by Gindalbie Metals, as a potential additional feedstock source. Hazelwood released new resource figures for Mulgine Hill in March 2011, which, based on a cut-off grade of 0.05% WO₃, included Indicated Resources of 10.16 Mt averaging 0.16% WO₃ and Inferred Resources of 5.35 Mt at 0.12% WO₃ for about 18 000 tonnes of contained W. The company also indicated that 95% of the resource is within 100 m of the surface.

Newcrest Mining Limited (Newcrest) released a maiden ore reserve and revised resource figures for its **O'Callaghans** polymetallic (tungsten-copper-zinc-lead) skarn deposit about 10 km south of Telfer in WA. The company reported Probable Reserves of 51 Mt grading 0.34% WO₃ contained within Indicated Resources of 69 Mt grading 0.34% WO₃ and Inferred Resources of 9 Mt grading 0.25% WO₃. Mineralisation occurs within a sub-horizontal polymetallic skarn at the contact between the O'Callaghans granite and limestone of the Proterozoic Puntapunta Formation. Newcrest is undertaking a prefeasibility study into the deposit, which is expected to be completed in the 2012-13 financial year. Based on its 2011-12 results, Newcrest is indicating potential development of the O'Callaghans deposit within the next five years, subject to board approval.

At its **Tallebung** tin-tungsten deposit, 70 km northwest of Condobolin in central NSW, YTC Resources (YTC) has commenced a Right to Negotiate Process under the Native Title Act to obtain access to undertake two deep drill holes aimed at testing targets from a previous resistivity survey (below outcropping mineralisation) and to assist in scoping of the Tallebung system for a potential large tonnage low-grade tin deposit. Previous trenching and drilling by YTC (2008 and earlier) has indicated broad low-grade tin-tungsten-silver mineralisation.

In 2011-12 Thomson Resources (Thomson) undertook exploratory drilling of magnetic targets in four prospects of the **Cuttaburra** and **Falcon** projects, spread over an east-west 40 km zone within the southern part of the undercover Thomson Orogen in northwest NSW. Thomson reported that drilling on the four prospects intersected evidence of mineralised hydrothermal systems, including alteration and mineralisation. Two of the targets gave high-grade polymetallic intercepts, particularly Au to 3.7 grams per tonne (g/t) and silver to 113 g/t, as well as Bi to 0.4%, Cu to 0.5%, lead to 1.8%, Sn to 0.8%, W to 0.6% and zinc to 4.25%. Mineralisation is reported to occur as sheeted and

stockwork veins up to a metre wide within zones of altered basement rocks of the Thomson Orogen. On the basis of the polymetallic assemblage, along with the presence of granite intersected in one hole, Thomson is suggesting an intrusion-related, gold-style of mineralisation. The company has planned additional drilling to test shallower parts of the mineralisation.

Following release of a resource estimate in April 2008 for the **Attunga** deposit 20 km north of Tamworth in NSW, Peel Exploration Ltd (Peel) undertook a study in 2010-11 to investigate development options which showed that conditions were favourable for a low-capital expenditure operation. Mineralisation at Attunga occurs within skarns developed at the contact of a lime-rich sequence with the Inlet Monzonite. There was no field activity in 2011-12, but in April 2012 Peel indicated it had begun a review of the Attunga deposit and was seeking potential joint venture or off-take partners.

Carpentaria Exploration Ltd continued work at its **Broken Hill** tin and tungsten project north of Broken Hill in NSW. The work was carried out at the historic **Euriowie and Waukeroo** Tin Fields, the historic Kantappa tin mine and the **Yanco Glen** scheelite (tungsten) deposit, which has an Inferred Resource of 0.83 Mt of 0.21% WO_3 . In 2012, Carpentaria undertook a drilling program at Yanco Glen to confirm the resource and test possible extensions. Intersections included 11 m at 0.47% WO_3 and 5 m at 0.86% WO_3 as well as 3 m at 0.15% WO_3 in a newly identified mineralisation zone about 1.5 km south of Yanco Glen. Interpretations of drill results are in progress. The company also undertook a mining option study which demonstrated that the Yanco Glen resource has potential for open-pit mining.

Cullen Resources has recently completed three exploration drill holes testing targets in the Doyenwae and Trig Orr prospects of its **Minter** Project area about 50 km northwest of West Wyalong in central NSW. Target areas were based on previously identified wolfram (tin and arsenic) geochemistry anomalies from soil sampling and prior shallow drilling. The company is targeting tungsten stockwork and vein-type mineralisation associated with granite cupolas of the Silurian Kikoira Granite.

Uranium

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Major uses for uranium (U) are as fuel in nuclear power reactors for electricity generation, in the manufacture of radioisotopes for medical applications and in nuclear science research using neutron fluxes.

On 11 March 2011, Japan suffered a major earthquake and tsunami which caused widespread devastation along the eastern coastal areas. The tsunami damaged and disrupted the emergency cooling systems at the Fukushima Daiichi nuclear power plant and this resulted in major damage to four of the six nuclear reactors at the site. Subsequently, this resulted in a substantial radiological release to the atmosphere (WNA⁷⁷, 2011).

In the wake of the incident, there have been a range of political responses issued by governments in many countries around the world. These political responses are summarised in AIMR 2011⁷⁸ (page 98).

Japan's nuclear power plants were shut down progressively for mandated periodic inspections when routine maintenance was due for each reactor. Local authorities refused to grant approvals to restart these plants and by early 2012 almost all of the 50 nuclear power plants (30% of Japan's total electricity generating capacity) were shut down. By mid-2012, two of the plants had resumed operations. The Japanese government is reviewing national energy policies and decisions will be made about the contribution of nuclear power to the country's electricity generation into the future (WNA, 2012⁷⁹).

The number of operating nuclear power plants worldwide declined from 442 at December 2010 (in 30 countries) to 434 by December 2011. Their share of world electricity generation also fell over the same period from 14% to 13.8% and the number of plants under construction worldwide fell from 63 to 61. By November 2012, the number of operating plants had increased slightly to 436 with a total capacity of 374 135 megawatts. The total uranium required to fuel these reactors is 68 000 tonnes a year (Source: World Nuclear Association).

Although the Fukushima accident has affected nuclear power projects and policies in some countries, nuclear power remains a key part of the global electricity mix. The Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) in the latest edition of the Red Book⁸⁰ stated:

"By the year 2035, world nuclear capacity, taking into account the current understanding of policies announced by some countries (e.g. Belgium, Germany, Italy and Switzerland) following the Fukushima accident is projected to grow to between about 540 GWe nett in the low demand case and 746 GWe nett in the high demand case, increases of 43% and 103% respectively. Accordingly, world annual reactor related uranium requirements are projected to rise to between 97 600 and 136 000 tonnes a year by 2035".

Uranium market prices:

For the first two months of 2011, the spot-market price continued to recover from the effects of the global financial crisis during late 2008 and early-to-mid 2009. Prices were bolstered by China's plans to expand its reactor fleet. In January, prices peaked for the year at US\$72 per pound (lb) U₃O₈. In March, the impacts of the Fukushima incident caused spot market prices to fall. Uncertainty continued in uranium markets and the spot price fell to its lowest value for the year of US\$49/lb in August. However, it recovered to US\$52/lb by September and remained at this level through to May 2012. Prices subsequently fell to US\$44/lb by the end of December 2012⁸¹.

The spot market has been adversely impacted by the uranium stocks held by Japanese nuclear power companies. This has been exacerbated by an increase in the release of uranium inventory by the United States Department of Energy which is currently selling approximately 3800 tonnes of natural uranium a year⁸². This represents more than 15% of annual reactor requirements in the US.

77 World Nuclear Association, 2011. Policy Responses to the Fukushima Accident. http://world-nuclear.org/briefings/policy_responses_fukushima_accident.html

78 https://www.ga.gov.au/image_cache/GA20563.pdf

79 World Nuclear Association, 2012. Nuclear Power in Japan. <http://world-nuclear.org/info/inf79.html>

80 Source: Organisation for Economic Cooperation and Development Nuclear Energy Agency and International Atomic Energy Agency, 2012: Uranium 2011: Resources, Production and Demand. OECD Nuclear Energy Agency, Paris 2012.

81 Source: The Ux Consulting Company, <http://www.uxc.com>

82 OECD Nuclear Energy Agency and International Atomic Energy Agency, 2011. Uranium 2011: Resources Production and Demand, p433.

Resources

Geoscience Australia prepares estimates of Australia's uranium resources within categories defined by the OECD/NEA and the IAEA. The resource categories within this NEA/IAEA scheme reflect total costs of mining and milling uranium ore.

In recent years, the cost of mining and milling uranium ores has increased in Australia as a result of the mining boom. Capital costs have risen and labour costs have increased more quickly than the national average⁸³. Prior to 2010, economic uranium resources were confined to the cost category of less than US\$80 per kilogram (kg) of uranium. However, because of increasing costs of mining and milling, most deposits/projects are now assigned to the higher cost category of less than US\$130/kg of uranium.

The estimates in each category are for resources of recoverable uranium after losses resulting from mining and milling have been deducted (Tables 17 and 18).

Table 17. Australia's uranium resources at December 2011 (reported under corresponding categories of NEA/IAEA and Australian national schemes).

National Scheme	NEA/IAEA Scheme	Tonnes U recoverable
Economic Demonstrated Resources (EDR)	Reasonably Assured Resources (RAR) recoverable at less than US\$130/kg U	1 196 000
Paramarginal Demonstrated Resources	RAR recoverable at US\$130–260/kg U	33 000
Submarginal Demonstrated Resources	RAR recoverable at greater than US\$260/kg U	0
Economic Inferred Resources	Inferred Resources recoverable at less than US\$130/kg U	539 000
Paramarginal Inferred Resources	Inferred Resources recoverable at US\$130–260/kg U	50 000
Submarginal Inferred Resources	Inferred Resources recoverable at greater than US\$260/kg U	0

Australia's RAR of uranium that could be produced at costs of less than US\$130/kg at December 2011 were estimated to be 1196 kilotonnes (kt), which was an increase of 3% on the estimates for December 2010.

Australia had an additional 539 kt of uranium in Inferred Resources recoverable at costs of less than US\$130/kg. These Inferred Resources are mainly in the southeast area of the Olympic Dam deposit in South Australia (SA).

Although there are more than 35 deposits with RAR of uranium recoverable at costs of less than US\$130/kg, the vast majority of these resources are within the following four deposits:

- Olympic Dam, which is the world's largest uranium deposit;
- Ranger and Jabiluka, in the Alligator Rivers region of the Northern Territory (NT); and
- Yeelirrie in Western Australia (WA).

⁸³ Port Jackson Partners, September 2012. 'Opportunity at Risk. Regaining our competitive edge in minerals resources'. Report prepared for the Minerals Council of Australia.

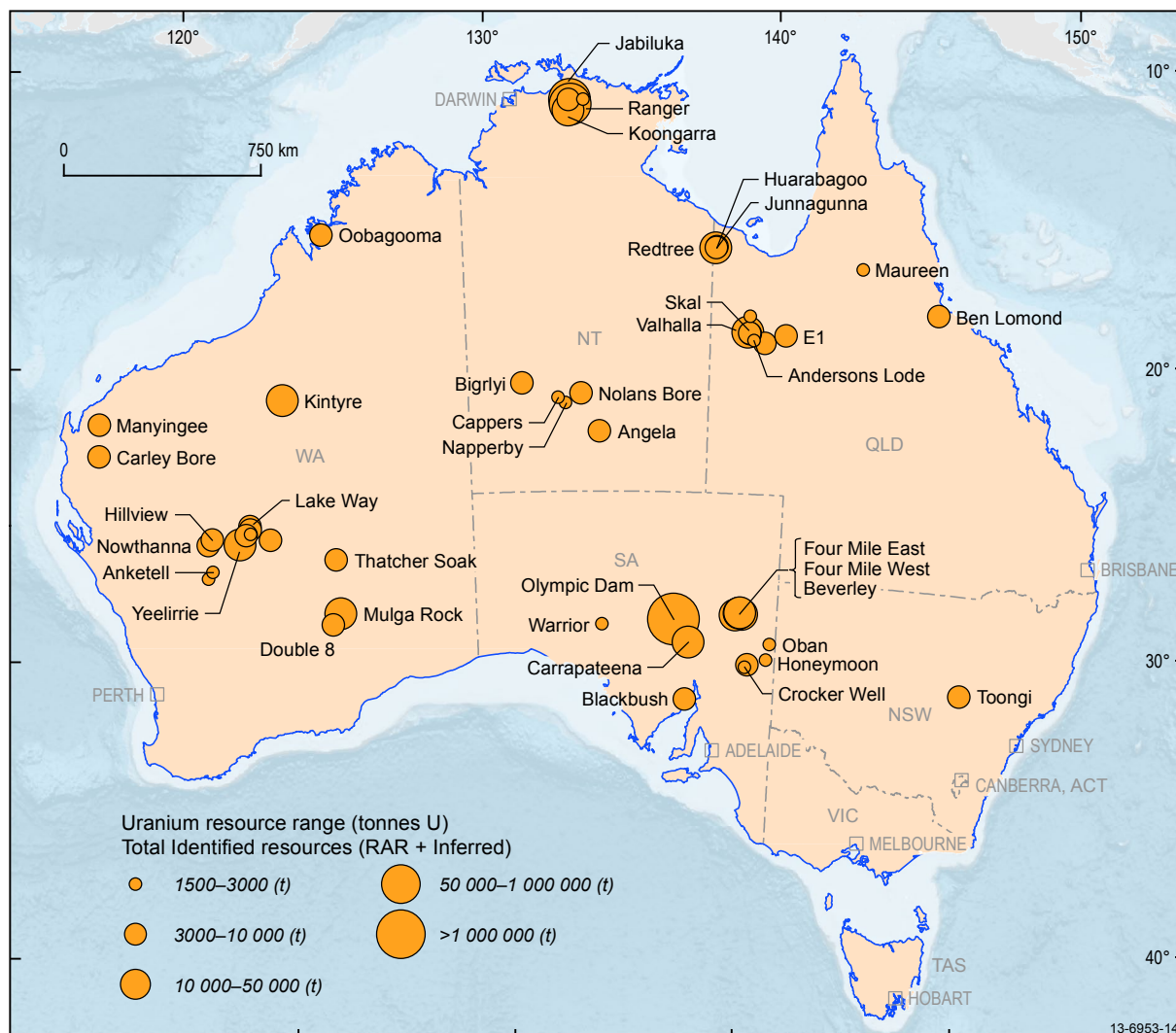


Figure 15. Australian uranium deposits with significant resources.

Table 18. Uranium resources in States and the Northern Territory at December 2011.

	RAR recoverable at <US\$130/kg U (Tonnes U)	Inferred Resources recoverable at <US\$130/kg U (Tonnes U)	Total Resources (Tonnes U)	Percentage of Australia's Total Resources (%)
South Australia	940 200	421 100	1 361 300	78
Northern Territory	164 700	59 000	223 700	13
Western Australia	55 300	39 000	94 300	6
Queensland	36 200	20 300	56 500	3
New South Wales	0	0	0	-
Victoria	0	0	0	-
Tasmania	0	0	0	-
Australia Total (rounded)	1 196 400 (1 196 000)	539 400 (539 000)	1 735 800 (1 736 000)	100

Accessible EDR

Approximately 10% of uranium in RAR at less than US\$130/kg (equates with Economic Demonstrated Resources) is inaccessible for mining. At December 2011, all uranium deposits in Queensland (Qld) were inaccessible because State Government policy at the time prohibited uranium mining. (Note: In October 2012, the Qld Government lifted its ban on uranium mining so that Qld deposits have become accessible since that date).

In the NT, inaccessible resources include the Jabiluka deposit, where the traditional Aboriginal land owners have not granted approval to mine the deposit, and the Koongarra deposit, which was added to the Kakadu World Heritage Area by the World Heritage Committee on 27 June 2011. In SA, the Mount Gee deposit is within the Arkaroola Protection Area, which was established by the SA Government in July 2011. Exploration and mining titles will not be granted in this area.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total uranium in Proved and Probable Ore Reserves as defined in the JORC Code. At December 2011, JORC Code reserves of 349 000 tonnes recoverable uranium accounted for approximately 32% of accessible Reasonably Assured Resource.

World ranking

Australia has the world's largest resources of uranium with an estimated 1196 kt in RAR recoverable at costs of less than US\$130/kg. Based on the latest estimates⁸⁴ for other countries, this represents approximately 34% of world resources in this category. Other countries with large resources in this cost category include Niger with 10%, Canada and Kazakhstan with 9%, Namibia with 7% and the United States with 6%.

Australia's Inferred Resources of uranium recoverable at costs of less than US\$130/kg are the world's largest resources in this category.

Exploration

Uranium exploration expenditure in 2011 was \$189.6 million⁸⁵ which was virtually unchanged from expenditure in 2010 (\$190 million). The majority of this expenditure was in WA (47%), followed by SA (24%), the NT (21%) and Qld (8%).

Uranium exploration expenditures in Australia have decreased progressively from a peak level of \$220 million in 2008 as spot-market prices decreased from highs in July 2007.

South Australia

Quasar Resources continued exploration for sandstone-hosted deposits in the Frome Embayment north of the Beverley Mine. Additional zones of mineralisation were intersected in Eyre Formation sands at **Pepegoona** and **Pannikin** deposits, which are 10 and 8 kilometres (km) north of Beverley mine respectively.

In 2011, Geoscience Australia released the results of a regional airborne electromagnetic (AEM) survey over the Frome Embayment. The results of this survey outlined the extent of paleochannel sands within the Eyre Formation. There has been increased activity in uranium exploration over the Frome Embayment. Cauldron Energy discovered uranium mineralisation in paleochannel sands to the north of Mount Babbage Inlier at its **MacDonnell Creek** prospect.

Exploration drilling continued at **Carrapateena** deposit, 100 km southeast of Olympic Dam. It is a hematite-breccia-complex deposit hosted by brecciated granites, similar to Olympic Dam. For details of resource estimates and results of metallurgical test work refer to AIMR 2011 (page 98).

Northern Territory

In 2011, Cameco Australia discovered high-grade uranium mineralisation at the **Angularli** prospect in western Arnhem Land. Exploration drilling targeted AEM survey anomalies where they coincided with major north-northwest-trending

84 Latest estimates for other countries as reported in 'U 2011: Resources Production and Demand'. OECD Nuclear Energy Agency and International Atomic Energy Agency, Paris.

85 ABS Mineral and Petroleum Exploration, December quarter 2011.

faults. Unconformity-related uranium mineralisation was intersected in both the basement rocks and the overlying Kombolgie Sandstone⁸⁶. The mineralisation is within a major breccia zone that postdates the Kombolgie Sandstones. Basement rocks comprise metasediments and felsic to intermediate magmatic rocks of the Nimbuwah Domain. Uraninite and pitchblende form veins, stringers and breccia matrix infill.

The best intersections at the Angularli prospect to date have been 12.2 metres (m) averaging 1.1% U₃O₈ followed by 20.2 m averaging 5.2% U₃O₈ within drill hole WRD0084.

In the Athabasca Basin in Canada, unconformity-related uranium deposits occur in breccia zones in two geological settings:

- in basement rocks below the unconformity (e.g. Key Lake, McArthur River, Rabbit Lake, Midwest deposits); and
- in overlying sandstones (e.g. Cigar Lake deposit).

The deposits above the unconformity are usually very high grade. To date, the known uranium deposits in the Alligator Rivers region (Ranger, Nabarlek, Jabiluka and Koongarra) are all within breccia zones in basement rocks below the unconformity. Deposits have not been found above the unconformity despite considerable exploration over the past decade by a number of companies. Angularli appears to be the first discovery of high-grade uranium mineralisation above the unconformity in the Kombolgie Sandstone.

Exploration drilling by Energy Resources of Australia in the Georgetown area, east of the **Ranger 3** open cut, intersected 14 m averaging 0.35% U₃O₈ from a depth of 403 m. The company plans to conduct a major exploration drilling program in the Ranger 3 Deeps and Georgetown area over the period 2012 to 2014 for a total expenditure of \$40 million.

During 2011, Alligator Exploration Ltd carried out exploration drilling in the **Caramal-South Horn** area within the Myra Inlier in western Arnhem Land. High-grade uranium mineralisation was intersected at Caramal deposit and a number of other locations.

At **Thunderball** deposit, near Hayes Creek, 140 km southeast of Darwin, unconformity-related mineralisation occurs in sheared carbonaceous shales, cherts and tuffaceous siltstones of the Pine Creek Orogen. In February 2011, Thundelarra Exploration Ltd released initial resource estimate of 829 000 tonnes Inferred Resources averaging 924 parts per million (ppm) U₃O₈, which represents 766 tonnes of contained U₃O₈.

In 2011, exploration drilling was directed at possible mineralisation along the contact between the Gerowie Tuff and the Zamu Dolerite approximately 70 m below the known mineralisation and along-strike extensions of the Lower Zone mineralisation. In addition, drilling was carried out at the **Bella Rose, Lady Josephine, Corkscrew** and **Moonraker** uranium prospects, with six holes returning intercepts above 100 ppm U₃O₈.

Several companies explored the northern margins of the Ngalia Basin (Mount Eclipse Sandstone) including Energy Metals, which, in a joint venture with Paladin Energy, continued regional exploration in the northern portion of the Basin between 180 km and 350 km northwest of Alice Springs. **Bigryli** is the main deposit in this area and other zones of mineralisation include **Walbiri**, and **Malawiri**. Drilling during 2011 intersected continuations of the mineralised zones at Anomaly 15 and Anomaly 4 within the Bigryli deposit. High-grade mineralisation was intersected at the **Camel Flat** prospect, in Mount Eclipse Sandstone 35 km southeast of Bigryli.

Exploration drilling continued at **Cappers** deposit where mineralisation is associated with calcareous alluvium. Toro Energy continued exploration at the **Napperby** deposit which is in calcrete on the northeast part of the Ngalia Basin.

In late 2010, Thundelarra Exploration completed a regional AEM survey over the company's 3300 square kilometres of exploration tenements within the Ngalia Basin. Interpretation of the data identified more than 400 km of paleochannel systems within the Lower Tertiary sequence. At the **Afghan Swan** prospect, conductivity data from the AEM survey defined the Lower Tertiary paleochannel system that hosts uranium mineralisation. Drilling identified significant uranium mineralisation (greater than 100 ppm U₃O₈) over 15 km within the Afghan Swan paleochannel.

Toro Energy completed an AEM survey in the **Wiso Basin** to explore for sandstone-hosted uranium mineralisation.

86 King, M., 2012. Exploration for unconformity-style uranium deposits: Geology and Mineralisation of the Angularli Prospect, Wellington Range Project, west Arnhem Land. AGES2012 Annual Geoscience Exploration Seminar. Northern Territory Geological Survey, March 2012.

Queensland

Paladin Energy Ltd continued exploration drilling in an area extending from 10 km to 110 km north of Mount Isa in northwest Qld. Exploration tenements are held in a joint venture with Summit Resources Ltd (82% owned by Paladin Energy) and Fusion Mineral Resources. There are more than 14 uranium deposits within these tenements, eight of which have significant resources. They are **Valhalla, Skal, Odin, Bikini, Andersons, Watta, Duke-Batman** and **Honey Pot** deposits. The total uranium resources in the Mount Isa region which are managed by Paladin and its subsidiary Summit Resources were reported to be⁸⁷:

- Measured+Indicated Resources 48 164 tonnes of U₃O₈ average grade 743 ppm U₃O₈; and
- Inferred Resources 18 466 tonnes of U₃O₈ average grade 574 ppm U₃O₈.

The largest of these is Valhalla deposit, which has total Measured+Indicated+Inferred Resources of 34 600 tonnes U₃O₈ with average grade 800 ppm U₃O₈.

During 2011 and 2012, drilling was mainly directed at upgrading the resources at Skal and Odin, while work on Valhalla included mineralogical and metallurgical testing. Drilling at Odin 1 km north of Valhalla and Skal intersected extensions to the deposit in a down-dip direction resulting in a significant increase in resources. At June 2012, estimated Indicated+Inferred Resources for Odin deposit were 7964 tonnes U₃O₈ at an average grade of 570 ppm U₃O₈ and the Indicated+Inferred Resources at Skal were 9885 tonnes U₃O₈ at an average grade of 630 ppm U₃O₈.

Recent metallurgical test work showed that Valhalla ore is amenable to high temperature and pressure alkaline leaching. Previous tests showed that the ore is very fine grained and sometimes refractory in nature. Alkaline leaching of the ore at high temperatures and pressures showed recoveries of 80 to 90%.

Western Australia

Several companies explored for sandstone-hosted uranium deposits in Cenozoic (Eocene) sands and lignite of the Gunbarrel Basin overlying the eastern margins of the Yilgarn Craton. Energy and Minerals Australia Ltd (EMA) continued exploration in areas adjacent to its **Mulga Rock** deposit, 250 km east-northeast of Kalgoorlie. In mid-2012, EMA reported the discovery of a new uranium deposit, the Princess deposit, within the Mulga Rock project area. Princess deposit is a tabular body 1.4 km long and ranges from 100 m to 500 m wide. It contains mineralised intervals up to 8.22 m thick with the top of the mineralisation 40 m below the surface. The best intersection to date is 8.33 m averaging 1360 ppm U₃O₈ at a depth of 38.4 m. The mineralisation is hosted by carbonaceous sandstone, siltstone and minor peat layers, and is immediately below the boundary between oxidised and reduced sediments. This boundary corresponds approximately with the water table. The Mulga Rock project comprises four separate uranium deposits, including the Princess deposit, which have total Inferred Resources of 27 100 tonnes of contained U₃O₈ with an average grade of 490 ppm U₃O₈.

Manhattan Corporation continued drilling into paleochannel sands at its **Ponton** project 180 km northeast of Kalgoorlie and 40 km southwest of Mulga Rock. The **Double 8** deposit and the **Stallion South, Highway South** and **Ponton** prospects are within the Queen Victoria Spring Nature Reserve (QVSNR). In addition, there are other uranium prospects within tenements to the north of the QVNR. Manhattan's four Exploration Licences that are within the QVSNR were granted in August 2011 and the company is seeking approval to drill the deposits within these tenements. The paleochannel drilling undertaken by Manhattan Corporation in 2011 was north of the QVSNR.

Toro Energy continued exploration at the **Theseus** prospect, in the Lake Mackay region in northeast WA adjacent to the NT border. Drilling intersected significant mineralisation in Cainozoic paleochannel sands adjacent to uranium-rich rocks of the Amadeus Basin. Drilling results have defined mineralised sands extending over an area 700 m wide, 2 km long, and open to the south. Age-dating of these sands confirmed that they are the same age as sediments of the Namba and Eyre Formation in the Callabonna Sub-basin which host the Beverley and Honeymoon deposits in SA.

Cameco Australia continued exploration at the **Turee Creek** and **Ashburton** prospects in the Bresnahan Basin about 150 km southwest of Newman. Low-grade uranium mineralisation occurs in the Kunderong sandstone. Current exploration is focused on the unconformity at the base of the sandstone.

Energy Metals continued exploration at the **Anketell** and **Lake Mason** calcrete-hosted deposits southwest of Wiluna.

Production

Australia's mine production for 2011 was 5967 tonnes U (7036 tonnes U₃O₈), which was 1% greater than for 2010. Australia had four operating uranium mines in 2011, Ranger in the NT and Olympic Dam, Beverley and Honeymoon in SA. At Ranger, very high rainfall during the wet season resulted in operations at the processing plant being suspended and total production for 2011 was restricted to 2240 tonnes U (2641 tonnes U₃O₈), compared to 3216 tonnes U in 2010.

Olympic Dam production for 2011 rose by 4% to 3353 tonnes U (3954 tonnes U₃O₈). Damage to the haulage system of the Clarke Shaft in 2009 reduced the mine's ore hoisting capacity in 2010. However the damage was repaired and full-year haulage was achieved during 2011. Production from Beverley in situ recovery (ISR) operation was 352 tonnes U (415 tonnes U₃O₈), which was unchanged from 2010. Production commenced at Honeymoon ISR operation in the latter part of 2011 and 22 tonnes U (26 tonnes U₃O₈) was produced for the year.

Total world production in 2011 was 54 610 tonnes U (64 399 tonnes U₃O₈), an increase of 2% on 2010. Most of the increase in production in 2011 is attributable to growth in Kazakhstan's output, which rose 9% to 19 451 tonnes U in 2011, Uzbekistan which rose 25% to 3000 tonnes U, and China which rose 80% to 1500 tonnes U in 2011. World uranium requirements for nuclear electricity generation in 2011 were 62 552 tonnes U⁸⁸. Uranium requirements in 2011 exceeded production by more than 7940 tonnes U.

Exports

Exports in 2011 were 5621 tonnes U (6628 tonnes U₃O₈) valued at \$586 million⁸⁹.

Exports of Australian uranium are controlled by stringent nuclear safeguards which ensure that it is used for peaceful purposes only and will not be diverted to military or explosive purposes. Australian mining companies supply uranium under long-term contracts to electricity utilities in the USA, Japan, China, South Korea and Canada as well as members of the European Union, including the United Kingdom, France, Germany, Spain, Sweden, Belgium and Finland. In 2011, major markets for Australian uranium were Asia (48.5%), Europe (25.7%) and the US (25.8%).

Industry developments

Olympic Dam (SA): BHP Billiton continued investigations into the Olympic Dam Expansion project based on a large open pit to mine the southeastern portion of the deposit. The company released the Supplement to the Environmental Impact Statement (EIS) for the Olympic Dam Expansion on 13 May 2011. The company received environmental approvals for the project from the Australian and South Australia Governments in October 2011 following assessment of the draft and supplementary Environmental Impact Statements.

On 29 November 2011, the South Australian Parliament ratified the *Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Bill*. BHP Billiton stated⁹⁰:

"The passage of this Bill provides the Company with greater certainty for what would be a significant investment and demonstrates South Australia's support for the project... We need to complete further studies on the project before seeking Board approval..."

In August 2012, the company announced⁹¹ that it would investigate an alternative, less capital-intensive design of the Olympic Dam open-pit expansion, involving new technologies, which would substantially improve the economics of the project. As a result, the company stated it would not be ready to approve the expansion before the Indenture agreement deadline of 15 December 2012. Heap leach and other technological solutions are being studied⁹² and these studies will require extensive analysis. BHP Billiton stated that current market conditions, including subdued commodity prices and higher capital costs, led to the decision to delay the project.

88 Source: World Nuclear Association website.

89 Australian Safeguards and Non-Proliferation Office, 2012. Annual Report of the Director General Australian Safeguards and Non-Proliferation Office 2011 – 2012.

90 South Australian Parliament ratifies Roxby Downs (Indenture Ratification) (Amendment of Indenture) Amendment Bill. BHP Billiton press release 29 Nov 2011.

91 BHP Billiton Olympic Dam update. 22 August 2012. Information release to shareholders.

92 Source: Base Metals briefing and Chilean site tour Non-ferrous overview. Andrew Mackenzie BHP Billiton. 30 September 2012. http://www.bhpbilliton.com/home/investors/news/Documents/2012/120930_BHPBillitonBaseMetalsBriefingSiteTour.pdf

Ranger mine (NT): During 2011, operations at the Ranger metallurgical processing plant were temporarily suspended because of the impact of very high rainfall during the wet season. In January 2011, Energy Resources of Australia (ERA) Ltd commenced an orderly suspension of plant processing operations as a proactive measure to manage water levels in the tailings storage facility during the wet season. Processing operations recommenced in June. Suspension of plant processing operations restricted total production for 2011 to 2240 tonnes U (2641 tonnes U_3O_8) compared with 3216 tonnes U in 2010.

The high water levels in Pit 3 restricted access to high-grade ore located at the bottom of the pit. Pit 3 is approaching the end of its operational life with the remaining ore in increasingly narrow, geologically complex zones within barren rock at the margin of the ore body.

Ranger 3 Deeps: This is one of the most significant uranium deposits recently discovered in Australia. It is estimated at 10 million tonnes of mineralised material with an average grade of 0.34% U_3O_8 for 34 000 tonnes of contained U_3O_8 . ERA propose to mine the deposit by underground methods.

In July 2012, excavation of the boxcut for the Ranger 3 Deeps exploration decline was completed and work commenced on the decline in November 2012. Close-spaced underground exploration drilling will be carried out from the decline to further define the Ranger 3 Deeps ore body and to explore adjacent areas. In parallel to construction of the decline, work is proceeding to prepare a feasibility study and to detail the approvals process associated with a potential Ranger 3 Deeps underground mine.

In addition to the underground drilling of the Ranger 3 Deeps deposit, an expanded \$40 million surface drilling program in under-explored areas of the Ranger Project Area is planned for 2012 to 2014.

ERA completed the feasibility study for a proposed heap-leach facility for extraction of U_3O_8 contained in low-grade mineralised material, mainly in stockpiles. In August 2011, the company announced that the study demonstrated that this facility was technically feasible, but the high capital costs and present economic assumptions limit its value. There was uncertainty also surrounding stakeholder support so the ERA Board decided not to proceed with the proposed heap-leach facility.

Beverley and Beverley North in situ recovery (ISR) mines (SA): Heathgate Resources operates the Beverley and Beverley North ISR mines between the North Flinders Ranges and Lake Frome, approximately 300 km northeast of Port Augusta. By 2010, most of the resources at Beverley deposit had been mined out, and, in recent years, the company has mined remnants of the resources within the Beverley mining lease. During 2011, production was mainly from old, reactivated wellfields, some of which closed several years ago. The company reactivated these old wellfields from where additional uranium was produced. The company continued exploration drilling within the Beverley leases during 2011.

Beverley North comprises the Pepegooona deposit, 12 km north of the Beverley mine and the Pannikin deposit, 10 km northwest of Beverley. Following assessment of the environmental impacts under the Environment Protection and Biodiversity Conservation Act (EPBC Act), formal approval by the Australian and South Australian Governments was granted in February 2011. Production commenced at Pepegooona in March and by November, both Pepegooona and Pannikin plants were in operation.

Beverley North is mined using a satellite ISR operation. The satellite operation comprises wellfields, pumps, pipelines and facilities for circulation of the mining (leach) solutions, and ion-exchange columns. Uranium is captured on resins within the ion-exchange columns. When the resin is loaded with uranium it is transferred into a road tanker and transported to the Beverley plant for metallurgical processing to recover the uranium. After the uranium has been removed, the clean resin is transported back to Beverley North for reuse in the ion-exchange columns.

During the latter part of 2011, combined production at Beverley plant was approximately 80% from Beverley North and 20% from the reactivated wellfields at Beverley deposit.

Four Mile ISR project (SA): Four Mile comprises two large sandstone-hosted uranium deposits, Four Mile West and Four Mile East, and is 75% owned by Quasar Resources (affiliate of Heathgate Resources) and 25% owned by Alliance Resources.

The granting of a mineral lease over Four Mile project had been delayed for several years as a result of legal proceedings between the joint venture partners on matters involving the registration of a Native Title Mining Agreement (NTMA). In early 2012, these matters were resolved and the NTMA was registered on 8 February 2012. On 26 April

2012, the joint venture was granted a 10-year mineral lease over the Four Mile project area by the South Australian Minister for Mineral Resources and Energy.

In October 2012, Alliance announced the decision to recommence development of the Four Mile Project. The Start-Up Plan comprises:

- uranium capture at Heathgate's Pannikin satellite plant with elution, precipitation, drying and packing at Beverley processing plant; and
- ISR mining operations commencing at Four Mile East in the December quarter, 2012 and at Four Mile West in the June quarter, 2013.

Quasar Resources has described the Start-Up Plan as a staged commencement of mining operations to allow actual production rates to be considered before full-scale production facilities are constructed.

Table 19. Four Mile Uranium Project - Mineral Resources at July 2012.

	Resources	Grade (% U ₃ O ₈)	U ₃ O ₈ (tonnes)	JORC Classification
Four Mile West	5.7 Mt	0.34	19 000	Total Indicated plus Inferred
Four Mile East	4.1 Mt	0.31	13 000	Inferred
Total	9.8 Mt	0.33	32 000	

All mineral resource estimates at Four Mile have been calculated using parameters for an ISR mining method. However, in the western area of Four Mile West, additional mineralisation has been identified above or within about 20 m of the watertable. This has the potential to add to mineral resources, if proved recoverable by ISR or mineable by other methods.

Honeymoon ISR mine (SA): Honeymoon ISR uranium mine is approximately 75 km northwest of Broken Hill. Uranium-bearing solutions are processed using solvent extraction technology at the processing facility. Pilot production (commissioning) at Honeymoon commenced in September 2011 and production for 2011 was 22 tonnes U (26 tonnes of U₃O₈). The first shipment of uranium concentrates from Honeymoon to the United States occurred in February 2012 and by mid-2012, 32 production wells were in operation.

The project has a design capacity of 880 000 lbs U₃O₈ per year (340 tonnes U per year). The groundwater treatment plant and the calcium sulphate removal circuit commenced operating in the late 2010 and early 2011.

Oban ISR project (SA): Field leach trials were carried out at the Oban deposit, about 100 km northwest of Broken Hill. Acid-leach solutions and an oxidant were used in the trials. A five-well pattern, comprising four injection and one central extraction well was used, which is similar to wellfield patterns at Beverley and Honeymoon.

Curnamona Energy reported that only low levels of uranium were recorded in leach solutions. It appears that the bulk of the uranium minerals are contained in thin (5 to 20 centimetre) bands of clay that occur in the sand units which were leached in the trials⁹³. Experiments with alternative lixiviants have dissolved some uranium in solution, but the rates of dissolution are low, and are not acceptable. Curnamona stated that this is because of the impervious nature of the clay bands. In early 2012, the company ended the trials and began rehabilitation work at the site. Exploration drilling continued in other areas of the tenements.

Sapphire project (SA): UraniumSA Limited continued evaluation drilling at Blackbush and Plumbush sandstone-hosted uranium deposits 20 km south of Whyalla on the eastern Eyre Peninsula. In 2011, uranium mineralisation was discovered in granite basement below the sediment-hosted uranium mineralisation and this became the focus of new exploration drilling within the tenements.

The Inferred Resources of sediment-hosted uranium mineralisation are:

- Blackbush deposit 45.5 Mt averaging 280 ppm U₃O₈ (12 700 tonnes contained U₃O₈); and
- Plumbush deposit 21.8 Mt averaging 292 ppm U₃O₈ (6300 tonnes U₃O₈).

93 Curnamona Energy Ltd, 2011. Annual report to Australian Securities Exchange, October 2011.

An evaluation of mining methods to optimise the recovery of uranium from the resources has commenced. This will include consideration of open-cut options in addition to an ongoing evaluation of in situ recovery methods.

UraniumSA continued research and development work on the extraction of uranium from saline solutions with a number of resins tested. Test work carried out by the Australian Nuclear Science and Technology Organisation using mineralisation from the Samphire project confirmed the suitability of four of these resins for potential commercial use. UraniumSA signed a Memorandum of Understanding with uranium extraction specialist Clean TeQ to test the suitability of the Clean TeQ's U-HiSAL process to extract uranium from acidified saline solutions at Samphire project.

Yeelirrie project (WA): The Yeelirrie deposit is 70 km southwest of Wiluna and is Australia's second largest undeveloped uranium deposit. It occurs in calcretes within a paleochannel and is at shallow depths down to 15 m below the surface. In August 2012, BHP Billiton signed an agreement to sell the Yeelirrie deposit to Cameco Corporation for US\$430 million. The sale was approved by the Australian Foreign Investment Review Board in November and by the Western Australian Government in December 2012.

Table 20 provides an estimate of the mineral resources for Yeelirrie prepared by BHP Billiton in June 2012.

Table 20. Mineral Resources Yeelirrie Project.

	Million tonnes	Grade (% U ₃ O ₈)	U ₃ O ₈ (tonnes)
Measured Resource	16.61	0.16	26580
Indicated Resource	31.03	0.12	37240
Inferred Resource	2.41	0.10	2410

Note: Cut-off grade = 0.05% U₃O₈.

The estimate was based on 10 250 surface holes, of which nearly 4000 diamond drill holes had assay values and the rest had uranium grade measured by downhole radiometric probing. Cameco considers this may be an overestimate of total uranium content. In order to revise the mineral resource estimate, Cameco propose to review the gamma logs and the grade-radiometry relationship, and recalculate the resources using a lower cut-off grade.

Wiluna project (WA): Operated by Toro Energy Limited, the project comprises two shallow (less than 8 m deep) calcrete-hosted deposits, Lake Way and Centipede, which are located 15 km south and 30 km south of Wiluna respectively. At December 2011, Lake Way had Indicated+Inferred Resources of 9.95 Mt averaging 530 ppm U₃O₈ (5280 tonnes of contained U₃O₈) and Centipede had total Measured+Indicated+Inferred Resources of 11.31 Mt averaging 493 ppm U₃O₈ (5579 tonnes of contained U₃O₈). Toro also owns three other calcrete-hosted deposits in the Wiluna region, the Millipede, Dawson Hinkler Well and Nowthanna deposits. These have total Indicated+Inferred Resources estimated of 30.98 Mt averaging 382 ppm U₃O₈ (11 782 tonnes of contained U₃O₈).

Metallurgical test work and studies showed that alkaline agitated leaching in tanks at elevated temperatures is the preferred process option. The company proposes to produce uranium concentrates containing approximately 820 tonnes U₃O₈ a year.

In March 2011, Toro submitted a draft Environmental Review and Management Program which was the basis for environmental assessment of the project by both the Australian and Western Australian Governments. In October 2012, Toro received environmental approval for the Wiluna Project from the WA Minister for Environment, completing the State Ministerial approval process. The Australian Government's environmental decision on the project has yet to be announced.

Lake Maitland project (WA): This is a calcrete-hosted uranium deposit 100 km southeast of Wiluna. It occurs as a single horizontal layer 1 to 3 m thick with the top of the mineralised zone 1 to 2 m below the surface. During 2011, Mega Uranium Ltd advanced its feasibility studies of the project and completed studies associated with two test pits which are each 34 m long by 19 m wide and 5 m deep. Both were mined in late 2010 which demonstrated that:

- truck and excavator mining methods are viable and that the ore and overburden can be excavated without blasting; and
- selective mining could be achieved using high precision Global Positioning System (GPS) equipment on an excavator.

The company also completed investigations into the radiometric disequilibrium of the calcrete ores. Uranium assays from chemical analysis of drill-core samples were compared with radiometric grades from corresponding intervals measured by downhole gamma ray logging of these holes. These comparisons showed that, on average, positive disequilibrium exists in the deposit and that downhole radiometric logging significantly understates the actual uranium grade. A considerable proportion of the drill-hole assays used to estimate the mineral resources for the deposit were from downhole gamma-ray logging.

Based on these disequilibrium data, Mega Uranium commenced a diamond drilling program at Lake Maitland in October 2011 with the aim of increasing the mineral resource tonnage and grade. This program was completed in early 2012 and analyses of the results will be reported when finalised.

Kintyre project (WA): Cameco Australia Ltd estimated the mineral resource at 31 March 2011 to be:

- Indicated Resources of 25 583 tonnes contained U₃O₈ at an average grade of 0.49% U₃O₈; and
- Inferred Resources of 2404 tonnes contained U₃O₈ at an average grade of 0.47% U₃O₈.

A prefeasibility study of Kintyre was completed and in July 2012 the company reported⁹⁴ that the study "...highlighted the project's challenging economics caused by low uranium prices and escalating costs in Western Australia." The prefeasibility study was based on a seven-year open-pit mine to produce around 6 million pounds (Mlb) of U₃O₈ a year (2300 tonnes U). The study found that to break even, the project would need an average realised uranium price of US\$67/lb or 62 Mlb (23 850 tonnes U) of production over its seven-year life, as opposed to 40 Mlb (15 380 tonnes U) in current resources.

The company stated that it would carry out further drilling aimed at discovering more resources and that the project was unlikely to start construction in 2014 as envisaged.

Bigrlyi deposit (NT): During 2011, Energy Metals completed a prefeasibility study at the Bigrlyi project which is located 300 km northwest of Alice Springs. These studies investigated mining the Bigrlyi deposit using a combination of open-pit and underground mining. The studies showed that processing the ore using acid leach would generate a positive cash flow for a mine life of eight years⁹⁵ and that a substantial increase in resources is critical to improve the economics of the project. Exploration drilling carried out during 2011 identified extensions of the Anomaly 4 deposit (Bigrlyi) in a down-plunge direction. Further mineralisation was intersected at the Anomaly 15 East deposit (Bigrlyi). Large-diameter cored holes were drilled to obtain samples for metallurgical testing and to provide geotechnical data for both open pit and underground mining studies.

Other developments

New South Wales Government lifts ban on uranium exploration

New South Wales (NSW) legislation allowing uranium exploration was proclaimed on 14 September 2012. The NSW Minister for Resources and Energy stated⁹⁶ that while the 26 year ban on uranium exploration has been overturned, the ban on uranium mining remained.

By November 2012, almost 40 expressions of interest to explore for uranium in NSW had been received. The Resources and Energy Minister said an expert panel would assess the applications and make recommendations to the Government about whether exploration licences should be granted⁹⁷.

Queensland Government lifts ban on uranium mining

On 22nd October 2012 the Qld Government announced it would convene a three-member implementation committee to oversee the recommencement of uranium mining. The Premier said the announcement followed sustained public debate on uranium mining and strong support for the uranium industry from the Australian Government.

The Qld Minister for Natural Resources and Mines said that with Qld's known uranium deposits worth an estimated \$10 billion, the industry had enormous potential to support economic growth, particularly in regional northwest Qld.

94 Kintyre uneconomic: Cameco. Press Release 30 July 2012. Cameco Corporation.

95 Energy Metals Ltd. Annual report for 2011.

96 Media release 15 September 2012 by NSW Minister for Resources and Energy.

97 Media release. Capital City Daily 21 Nov 2010.

Uranium mining has not occurred in Qld since 1982 and has been effectively prohibited by the State Government since 1989. However, exploration for uranium has not been subject to the prohibition and there has been significant interest from the industry in exploring for uranium in the State.

Protection areas declared

The **Koongarra** area, along with the uranium deposit, was added to the Kakadu World Heritage Area by the World Heritage Committee on 27 June 2011 in recognition of the areas important natural and cultural values. The inclusion of Koongarra into the Kakadu World Heritage Area means that it will have protection under the EPBC Act.

On 22 July 2011, the Premier of SA announced establishment of the **Arkaroola** Protection Area, which will be reserved from operation as a result of the Mining (Reservation from Act) Proclamation 2011 under section 8 of the SA Mining Act. It is proposed to enact legislation protecting the area and follow that with an application for World Heritage Listing. As a result, future exploration and mining titles will not be granted in the designated area. This will prevent mining in the area covered by Marathon Resources' **Mount Gee** exploration licence (EL 4355).

Vanadium

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Vanadium (V) is a soft, ductile, silver-grey metal that is used primarily with iron to make metal alloys for high-strength steel production. High-strength steel has a wide range of applications, including for gas and oil pipelines, tool steel, jet engines, the manufacture of axles and crankshafts for motor vehicles, as well as for reinforcing bars in building and construction.

Vanadium is also used in the production of ceramics and electronics, textile dyes, fertilisers, synthetic rubber, in welding, as well as in alloys used in nuclear engineering and superconductors. Vanadium chemicals and catalysts are used in the manufacture of sulphuric acid, the desulphurisation of sour gas and oil and in the development of fuel cells and low-charge-time, light-weight batteries.

Vanadium is not found in its metallic form in nature but occurs in more than 60 minerals as a trace element in a number of different rock types. It occurs most commonly in titaniferous magnetite deposits and in uraniferous sandstone and siltstone, as well as bauxites and phosphorites. It also occurs in fossil fuel deposits such as crude oil, coal and tar sands. It is produced as both a primary product and co-product from mining and most commonly as co-products or by-products of steel making. It is also recovered from wastes such as fly ash, oil residues and waste solutions from the processing of uranium ores.

Nearly all of the world's vanadium is derived from mined ore as either direct mineral concentrates, usually vanadium- and titanium-rich magnetite, or as a by-product of steel-making slags. The United States Geological Survey (USGS) estimates that almost 70% of annual supply is recovered from slags and about 30% directly mined, with the remainder being acquired from other sources. Japan and the United States are thought to be the only countries to recover significant quantities of vanadium from petroleum residues.

Vanadium is sold as vanadium pentoxide (V_2O_5) and less commonly as vanadium trioxide (V_2O_3) for non-steel applications and as the alloy ferrovanadium (FeV) for steel making. The most common FeV alloy is FeV80, but FeV40, FeV50 and FeV60 are also sold. The numeric part of the symbol refers to the amount of contained vanadium; for example, FeV80 has approximately 80% contained vanadium.

Trade in vanadium products tends to be opaque with no central market recording prices. Various trade sheets such as the Metal Pages, Ryan's Notes and the London Metal Bulletin record proprietary information for subscribers. Sourcing Ryan's Notes, the USGS states that in 2011 the average price for FeV in North America ranged from US\$14.606 to US\$15.004 per pound (lb) of vanadium content, compared to US\$14.155 to US\$14.688/lb in 2010. In 2011, the European average price for FeV, ranged from US\$28.533 to US\$29.273 per kilogram (kg), compared to US\$29.811 to US\$30.817/kg in 2010. Average prices in 2012 to 30 September for FeV have ranged from US\$32.14 to US\$32.45/kg in the North American market and US\$24.45 to US\$25.53/kg in European markets. The USGS also reports the Ryan's Notes annual average price for V_2O_5 in the United States ranged from US\$6.563 to US\$6.960/lb in 2011, compared with US\$6.285 to US\$6.636/lb in 2010. Ferrovanadium has a price premium over V_2O_5 .

Historically, vanadium prices have fluctuated over the past decade with sharp rises and equally sharp declines over short periods. For example, following the global financial crisis, FeV prices reached lows of US\$16.30 and US\$17.50/kg in May 2009 in North America and Europe, respectively, after reaching heights of about US\$101.40 and US\$93.00/kg, respectively, the previous year.

Resources

Australia's Economic Demonstrated Resources (EDR) of vanadium decreased by 14% in 2011 to 1519 kilotonnes (kt) from 1762 kt in 2010 as a result of a reassessment of the Gabanintha deposit in Western Australia (WA) by Yellow Rock Resources Ltd.

Historically, Australia's EDR of vanadium have fluctuated because of the economic impacts of volatile prices and the nature of the vanadium market, which is supplied largely from secondary sources, particularly the reprocessing of slags from iron smelting. These secondary sources are able to rapidly increase or decrease output in response to price trends.

Accessible EDR

All of Australia's EDR of vanadium are accessible.

JORC Reserves

In 2011, Joint Ore Reserve Committee (JORC) Code Reserves in the Proved and Probable Reserve categories comprised 1230 kt of vanadium compared with 1172 kt in 2010. This accounts for approximately 81% of accessible EDR. The remaining 19% of EDR comprises Measured and Indicated Resources.

World Ranking

The USGS estimates that world economic resources of vanadium are about 15 million tonnes (Mt) but total world resources exceed 63 Mt. China and Russia each hold about 8% of the world's vanadium resources, followed by South Africa with 6%. Australia's EDR of 1.519 Mt represents approximately 2.5% of the world's vanadium resources. However, because vanadium can be recovered as a by-product or a co-product of steel slags, the estimated world resources are not fully indicative of available supply. At current usage, there are sufficient resources to meet the world's vanadium needs into the next century.

The USGS estimates that world production of vanadium from all sources in 2011 totalled 62.4 Mt compared to 62.2 Mt in 2010, with China producing 23 Mt, South Africa 22 Mt and Russia 15 Mt.

Exploration

Data on exploration expenditure for vanadium are not available in published statistics. However, during 2011, exploration or resource drilling was undertaken at Speewah in WA with approximately 13 000 m of reverse circulation (RC) drilling and 5000 m of diamond drilling, while at Hawkwood in Queensland (Qld) there was 637 m of diamond drilling following the 2010 RC-drilling campaign. More recently, a 7000 m diamond and RC drilling program commenced in November 2012 at Mount Peake in the Northern Territory (NT). Geochemical and geophysical surveys were undertaken in WA at Gabanintha in 2011 and 2012 and at Canegrass in late 2011. Exploration of the southern tenements at Windimurra in WA confirmed the potential for replenishing the reserves at this mine.

Production

There was no production of vanadium in Australia during 2011. However, Atlantic Ltd's Windimurra mine produced vanadium and high-titanium hematite fines (iron ore) in 2012. The company's first shipment of seven tonnes of FeV occurred at the end of May and by the end of September it had transported another 38 tonnes to its Perth warehouse.

Most of the world's reported mine production of vanadium during 2011 was in China (38%), South Africa (33%) and Russia (25%).

Industry Developments

Windimurra (WA): The Windimurra mine, operated by Atlantic Ltd, is the only producing vanadium mine in Australia. It started producing in January 2012 and by the end of September the company had transported some 45 tonnes of ferrovanadium to its Perth warehouse. Improvements in the mine processing plant are expected to enable production to increase significantly with the company planning to produce 6300 tonnes per annum of vanadium once the mine and plant are fully operational. The projected mine life for Windimurra is approximately 28 years.

In 2011, the Windimurra deposit contained 20% of Australia's total EDR of vanadium. In May 2011, Atlantic Ltd published a Proven and Probable Reserve of 127.6 Mt at 0.47% V₂O₅ for the Windimurra vanadium project. A more recent Measured, Indicated and Inferred Resource of 242.6 Mt at 0.48% V₂O₅, representing 654 000 tonnes of contained vanadium, was published in April 2012.

The mine also has potential to produce hematite fines as a by-product of FeV processing. Significant stockpiles of hematite fines remain at the mine site, leftover from the previous Xstrata operation that ran for three years until the mine closed in 2004. Windimurra's iron-ore fines also possess a high titanium grade, leading the company to successfully

test for the optimal processing flow for separating the iron and titanium dioxide from the ore. This work was done in conjunction with the Changsha Research Institute of Mining and Metallurgy in China at both laboratory and process scale and confirmed that separation of the iron-ore fines is a viable business opportunity for the Windimurra operation.

Speewah (WA): During 2011, Speewah Metals Ltd drilled 266 holes for more than 18 000 m at the Speewah titanium-vanadium-iron deposit. The company completed hydrometallurgical testwork in February that confirmed a mixed chloride leaching process could be used to extract the titanium, vanadium and hematite. In March 2012, the company released a new JORC Code compliant resource for the deposit of 4712 Mt at 0.3% V₂O₅, 2.0% titanium (Ti) and 14.7% iron (Fe), an increase of 32% over the previous resource estimate. In April 2012, the company completed a scoping study and, in May 2012, signed a Memorandum of Understanding (MoU) with the traditional owners of the land. In September 2012, the company suspended activities at Speewah, citing limited funding and an unfavourable outlook for financing.

Balla Balla (WA): In December 2011, Atlas Iron signed a binding agreement to sell its Balla Balla vanadium-magnetite-titanium project to Forge Resources Ltd. Subsequently, Forge Resources formed a joint venture with a New Zealand private equity company, Todd Capital, and the mine was sold in May 2012 for \$40 million. A Definitive Feasibility Study (DFS) was completed in February 2010 which concluded that the project is economic. Total resources are currently 456 Mt at 45% Fe, 0.64% V₂O₅ and 13.7% TiO₂. Forge Resources is currently revising the DFS, exploring trans-shipment export paths, trialling products and seeking project finance.

Barrambi (WA): In June 2011, Reed Resources entered into a MoU with China Non-Ferrous Metal Industry's Foreign Engineering and Construction Company Ltd and Arcon (WA) Pty Ltd for the development of the Barrambi Vanadium Project. However, by September 2011 the companies suspended the MoU citing weak market conditions for vanadium. Since then, Reed Resources has been conducting laboratory-scale testwork on the Eastern Band magnetic concentrates from the Barrambi iron-titanium-vanadium deposit with plans for a mini-plant (150 kg) testwork program. Current resources total 65.2 Mt at 0.82% V₂O₅ and 17.3% TiO₂.

Gabanintha (WA): Yellow Rock Resources Ltd released a new resource estimate in February 2011 for the Gabanintha titanium-vanadium-magnetite project with higher grades but reduced tonnage. Indicated and Inferred Resources have decreased from 151.5 Mt to 125.8 Mt at 0.7% V₂O₅, 8.6% TiO₂ and 32% Fe. The company undertook a comprehensive geochemical soil sampling program, which was completed in December 2011, and a helicopter-borne geophysical survey completed in July 2012.

Canegrass (WA): Flinders Mines Ltd released an Inferred Resource statement in August 2011 for the Canegrass magnetite project of 107 Mt at 0.6% V₂O₅, 5.8% TiO₂ and 29% Fe.

Unaly Hill (WA): In November 2011, Black Ridge Mining NL announced a maiden Inferred Resource for the Unaly Hill vanadium-titanium-magnetite project of 86.2Mt at 0.4% V₂O₅, 4.5% TiO₂ and 24% Fe.

Victory Bore (WA): In March 2011, Quest Minerals Ltd announced a maiden Inferred Resource for the Victory Bore vanadium-magnetite-titanium deposit of 151 Mt at 0.4% V₂O₅, 6.7% TiO₂ and 25% Fe. Results from a subsequent metallurgical scoping study released in January 2012 indicate that the ore is amenable to standard processing with a high recovery of vanadium. However, results from the July 2012 mining scoping study show that capital costs are the major factor in determining the project economics.

Mount Peake (NT): In February 2011, TNG Ltd completed a Scoping Study of the Mount Peake vanadium-titanium-magnetite project that indicated a potential mine could produce approximately 107 Mt of ore over 24 years. The company subsequently commissioned another scoping study on the potential of producing FeV at a downstream plant. In October 2011, TNG released an updated JORC Code Resources statement of 158 Mt at 0.28% V₂O₅, 5.06 % TiO₂ and 22% Fe for the Mount Peake project. Activities in 2012 included the release of a pre-feasibility study in July and the start of a 7000 m diamond and RC-drilling program in November.

Julia Creek (Qld): In June 2011, Intermin Resources Ltd reported a total resource of 5308 Mt at 0.37% V₂O₅ and 312 grams per tonne molybdenum. The company also carried out metallurgical testwork and has a feasibility study in progress. However, progress on this project is hampered by the Queensland Government's moratorium on oil shale mining, which affects the Julia Creek vanadium-molybdenum project as it is hosted by calcareous oil shales in the Toolebuc Formation.

Hawkwood (Qld): During 2011, Eastern Iron Ltd drilled three diamond drill holes into the Hawkwood orebody and sent the core for Davis Tube analysis. In May 2012, the company released a maiden Inferred Resource statement for the Hawkwood Iron Project of 103.7 Mt at 64.6% Fe, 1.83% TiO₂ and 0.05% V. Davis Tube concentrates gave results of 66.6% Fe, 2.2% TiO₂ and 0.67% V₂O₅.

Zinc, Lead, Silver

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Zinc (Zn) is the 23rd most abundant element in the Earth's crust and the 4th most common metal in use after iron, aluminium and copper. The construction, transport and appliance manufacturing industries use large amounts of zinc, mainly as anti-corrosion coatings (galvanising) on sheet steel, steel beams, vehicle panels, chain-link fencing, guard rails and light posts. Worldwide, galvanising accounted for 50% of the world's total consumption of zinc in 2011 (consumption data from www.ilzsg.org). The widespread use of zinc as a protective coating is due mainly to its resistance to weathering as a consequence of an electrochemical reaction known as galvanic action. Zinc is more reactive than iron or steel and consequently attracts almost all local oxidation. A protective surface layer of oxide and carbonate forms as the zinc corrodes. Zinc is used also in brass (17% of zinc consumption), other alloys (17%), with the balance in other uses such as pigments, salts, oxide additives to rubber and agricultural chemicals (16%). Zinc metal is produced in Australia at Sun Metals Corporation's Townsville refinery in Queensland (Qld) and at Nyrstar NV's Hobart refinery in Tasmania (Tas).

The widespread occurrence of **lead** (Pb), its relatively simple extraction and a combination of desirable properties have made it useful to humans since at least 5000 BC. In deposits mined today, lead, mainly in the form of galena (PbS), is usually associated with zinc, silver (Ag) and sometimes copper (Cu) and is extracted as a co-product of those metals. The largest use is in batteries for vehicles, which accounts for 80% of modern lead usage. The remaining 20% of applications include weights and ballast, underwater cable sheathing, solder, casting alloys, chemical compounds, including PVC plastics and pigments, ammunition, glassware and radiation protection. Uses for lead could increase in the future in large-storage batteries used for load-levelling of electrical power and in electric vehicles. The growing popularity of electric bikes, particularly in China, has led to an increase in demand for lead to make batteries for e-bikes. More than half of the lead currently used is from recycling rather than from mining. Of the 10.49 million tonnes (Mt) consumed in 2011, only 4.67 Mt was primary mine production (www.ilzsg.org). Lead recycling plants jointly owned by Nyrstar NV and the Sims Group are in Melbourne, Victoria (Vic) and in Sydney, New South Wales (NSW). Nyrstar NV's Port Pirie smelter in South Australia (SA) is the world's largest primary lead smelting facility and a leading global silver producer.

The relative scarcity, attractive appearance and malleability of **silver** make it suitable for use in jewellery, ornaments and household silverware. Its extensive use in coins throughout history has declined over the past 50 years. In Australia, the 1966 50-cent piece was the last coin in general use to contain silver (80% Ag, 20% Cu). Silver is mined and produced mainly as a co-product of lead, zinc, copper and, to a lesser extent, gold (Au). In 2011, the global supply totalled 32.4 kilotonnes (kt) of which 23.7 kt was mine production (73%) with the balance from scrap and government sales. Consumption was dominated by industrial applications (15.1 kt or 47%), followed by fabrication (10.1 kt or 31%: 5.0 kt for jewellery, 3.7 kt for coins and medals, and 1.4 kt for silverware), and photography (2.1 kt or 6%). The balance of consumption was nett investment of 5.1 kt (16%). The use of silver in the photographic industry has declined steadily since the development of digital photography, declining over the past decade from 6.3 kt in 2002 to 2.1 kt in 2011 (source of supply and demand data: www.silverinstitute.org). Industrial uses of silver are varied and include electronics such as batteries and solar panels, coatings for mirrors, catalysts, construction of high quality musical instruments, biocides in many different guises and many other applications. The use of silver as a biocide to prevent bacterial and fungal growth in plastic and textiles as well as an antibacterial agent in topical gels, the treatment of wounds and in water treatment is growing and largely replacing the photographic industry as a major use.

Resources

Australia's total resources of zinc, lead and silver rose by nearly 5% in 2011. Total identified resources of zinc increased from 94 Mt in 2010 to 97 Mt in 2011 while lead rose by 2 Mt in 2011 to 62 Mt and silver rose by 6 kt to 131 kt.

Zinc

Australia's Economic Demonstrated Resources (EDR) of zinc increased by 3 Mt to 68 Mt in 2011 and accounted for around 26% of world economic resources representing the world's largest holding. Queensland continued to hold the largest resource with 38 Mt, or 55% of national EDR, predominantly at the George Fisher, Mount Isa, Century and

Dugald River deposits. The Northern Territory (NT) had the second largest EDR with 19 Mt, or 28% of national EDR, almost all of which is at the McArthur River deposit. Following was NSW with 5 Mt EDR, mostly at the Broken Hill and Endeavor deposits, Western Australia (WA) with 3 Mt, mostly at the Golden Grove, Sulphur Springs and Bentley deposits, and Tasmania with 2 Mt, mostly at Rosebery. Total Inferred Resources of zinc increased by 3 Mt to 27 Mt in 2011.

Lead

Australia's EDR of lead increased by 1 Mt in 2011 to 36 Mt of contained lead and constituted 58% of Australia's total identified lead resources (62 Mt). Australia also accounts for the largest share of world economic resources for lead at 39%. Queensland retained the top ranking with its EDR increasing from 19 Mt in 2010 to 20 Mt in 2011 representing a 57% share of national EDR which is mostly at the Mount Isa, George Fisher, Cannington and Lady Loretta deposits. The NT EDR of lead ranks second with 8 Mt or 23% of the national total, almost all of which is at the McArthur River mine. New South Wales has lead EDR of 4 Mt and WA has 2 Mt. Australia's Paramarginal Demonstrated Resources of lead decreased by 1 Mt to 3 Mt, which is 5% of total Identified Resources, as more of the older resources are re-estimated under the Joint Ore Reserve Committee (JORC) Code. Total Inferred Resources of lead increased slightly in 2011 to 22 Mt.

Silver

EDR for silver increased by 11 kt in 2011 to 88 kt, which represents 16% of world economic resources. Queensland has 52 kt or 59% of Australian EDR, mainly in the Mount Isa, Cannington, George Fisher, Dugald River and Century deposits. Most other silver EDR occurs in SA (11 kt), NSW (10 kt), the NT (8 kt), WA (3 kt) and Tas (3 kt). In SA, most silver EDR is at Olympic Dam with some at Prominent Hill, while in NSW it is mostly at Broken Hill and Endeavor. In the NT, silver EDR is nearly all at McArthur River, while in WA it is predominantly at Golden Grove, Spinifex Ridge and Bentley, and in Tas it is largely at Rosebery.

Accessible EDR

All zinc, lead and silver EDR is accessible.

JORC Reserves

Of Australia's AEDR of zinc, 33% occurs in the Joint Ore Reserve Committee (JORC) Code ore reserves categories. The remaining AEDR is made up of those measured and indicated resources as reported by mining companies and which Geoscience Australia considers will be economic over the long term. The zinc resource life using national AEDR divided by annual production is 45 years, but using the ore reserve and dividing by annual production gives a resource life of only 15 years.

Of Australia's AEDR of lead, 35% occurs in the JORC Code ore reserves categories. For lead, the national AEDR/production ratio is 58 years, but if the ore reserve/production ratio is used it is 20 years.

For silver, JORC Code reserves account for around 32% of AEDR and resource life is 51 years for AEDR or 16 years for JORC Code reserves.

Exploration

In 2011, exploration spending on zinc, lead and silver was \$83 million, 24% higher than in 2010. The 2011 expenditure was 11% of the total base metal expenditure of \$741 million compared to 12% in 2010. Expenditure on exploration for the three commodities made up only 2.3% of all mineral exploration of \$3.57 billion (excluding petroleum), and compared to 2.7% of \$2.49 billion in 2010. New South Wales and WA accounted for over half of the 2011 zinc, lead and silver exploration expenditure.

Production

According to the Bureau of Resources and Energy Economics (BREE), 2011 Australian mine production of zinc, lead and silver was 1.51 Mt, 0.62 Mt and 1.73 kt, respectively. Compared to 2010, production in 2011 increased by 2%

for zinc, but decreased by 13% for lead and was down 8% for silver. The majority of production was from Qld which contributed 1008 kt, or 67% to national zinc production during 2011 (up 14 kt on 2010) along with 444 kt, or 72% of lead (down 30 kt) and 1.35 kt, or 78% of silver. Western Australia produced 90 kt of zinc and 17 kt of lead with both decreasing over the 2010 production levels of 99 kt of zinc and 96 kt of lead. The large decrease in lead production in WA resulted from a further suspension of operations at the Magellan lead mine. Elsewhere, NSW produced 111 kt of zinc and 78 kt of lead while the NT produced 191 kt of zinc and 39 kt of lead and Tas produced 97 kt of zinc and 35 kt of lead. In all of these States, production of zinc and lead increased from the levels in 2010.

The Century zinc mine, which is located close to the Gulf of Carpentaria about 250 kilometres (km) north of Mount Isa in northwest Qld, ranks in the top few globally in zinc production. Century produced 497 kt of zinc and 27 kt of lead as metal in concentrate in 2011. The Cannington mine, also located in northwest Qld, is the world's largest and lowest-cost single mine producer of both silver and lead as well as a significant producer of zinc. Cannington produced 232 kt of lead, 1001 tonnes of silver and 60 kt of zinc in 2011. Also in Qld are Xstrata's Mount Isa operations which, in 2011, produced 357 kt of zinc, 131 kt of lead and 204 tonnes of silver, including 32 tonnes in silver from purchased concentrate.

The value of Australia's exports of zinc concentrates and refined zinc in 2011 totalled \$2414 million, 2% more than the \$2376 million in 2010 and 1% of the value of total merchandise exports. The amount of zinc exports increased by 4% to 1.55 Mt in 2011. The average price for zinc in 2011 was \$2350/tonne, 3% lower than the average of \$2419/tonne in 2010. The 2011 December quarter average price was 17% lower than for the December quarter in 2010.

Exports of lead totalled 691 kt in 2011, up 5% on 2010. The value of the 2011 exports was 13% higher at \$2181 million compared to \$1938 million in 2010. The average price for lead was \$2631/tonne in 2011 and only slightly lower than in 2010. However, lead prices were 13% lower when comparing December quarters. For silver, the average price was 53% higher at \$1061/kilogram (kg) compared to the average of \$695/kg in 2010 with a 13% December on December increase. The value of Australia's mine production of silver was \$1836 million in 2011, up 40% on 2010.

World Ranking

Based on United States Geological Survey data for other countries, Australia has the world's largest economic resources of zinc (26%), lead (39%) and ranks second for silver with 16% after Peru (22%). In terms of production, Australia ranks second for zinc and lead after China and fourth for silver after Mexico, Peru and China.

Industry Developments

Mount Isa (Qld): Mount Isa zinc-lead operations commenced production in 1931 and were acquired by Xstrata Plc in 2003. Operations currently comprise the George Fisher underground mine, the open cut mines of Black Star and Handlebar Hill, an eight million tonnes per annum (Mtpa) capacity zinc-lead concentrator, a lead smelter and a zinc filter plant. Following a major restructuring in 2009, there have been major increases in production in the Mount Isa operations that continued into 2011. Mined volumes increased by 6% to 9.09 Mt, and ore treated increased by 8%, to 9.23 Mt in 2011. However, lower head grades resulted in only a small increase in zinc in concentrate to 0.357 kt from 0.355 kt in 2010 and a small decrease in lead with combined in-concentrate and bullion down to 0.269 kt from 0.284 kt in 2010⁹⁸. These results contributed to a profit of \$105 million for Xstrata's Australian zinc operations, which included McArthur River (see below), compared to \$270 million in 2010. The lower profit is the result of reduced zinc prices in the second half of the year, a re-evaluation of open sales at year's end, a stronger Australian dollar and increased cost of energy and other mining consumables.

During 2011 and the 2012, Xstrata continued to expand its Mount Isa operations. The Black Star Deeps and Handlebar Hill expansions were completed in October and December 2011, respectively, and expansion of the George Fisher underground mine was begun. A decision was made in May 2011 to accelerate development of the Lady Loretta deposit northwest of Mount Isa. First ore production at Lady Loretta was achieved in September 2012, with ore to be trucked 140 km to the Mount Isa milling operations.

McArthur River (NT): Underground mining at McArthur River began in 1995, with open cut mining beginning in 2009. Xstrata Plc also acquired the McArthur River operations in 2003. The conversion to open-cut mining combined with a concentrator expansion increased production capacity to 2.5 Mtpa in 2009. Despite weather-related slowdowns in

⁹⁸ Cited values for zinc and lead production are from the 2011 Xstrata production report and differ for the payable metal values reported in the 2011 Xstrata annual report.

the first quarter, ore treated increased by 5% to 2.34 Mt in 2011. Slightly higher zinc grades combined with the greater throughput resulted in an increase in zinc in concentrate of 6% to 194 kt, and production of lead in concentrate increased by 21% to 38.3 kt. In March 2011, Xstrata announced a \$270 million plan to more than double concentrate production from McArthur River. If the development plan is approved by Xstrata and government regulators, mine life will be extended by six years to 2033.

Century (Qld): The Century Mine is one of the world's three largest zinc mines, producing 4% of global production. Minerals and Metals Group (MMG), a Chinese-owned corporation, acquired the Century, Rosebery and Golden Grove mines, amongst others, in early 2009. Production at the Century Mine in 2011 was similar to that in 2010, despite severe weather in the first quarter. During 2011, production of zinc in concentrate decreased slightly by 3% to 497 kt, while lead-in-concentrate increased by 5% relative to 2010 to 26.5 kt. Total payable silver production was 3.8 tonnes, a decrease of 47% relative to 2010, resulting from a decrease in grade. The December production of zinc at 54.26 kt was the highest recorded. Because of the inclusion of stage 10 development, mine life will extend to 2016. An 18-month exploration program in 2009-10 failed to identify new resources at the mine, or in adjacent exploration leases.

Cannington (Qld): The Cannington deposit in northwest Qld was discovered in 1990 by BHP-Billiton, with mining operations commencing in 1997. Mine production in 2011 increased marginally by 2% to 1.60 Mt on that achieved during 2010, while mill throughput increased by 8% to 1.71 Mt. A significant reduction in silver head grades reduced silver production by 17% to 1.0 tonne. Lead-in-concentrate also decreased by 8% to 232 kt, also because of lower grades while zinc-in-concentrate remained unchanged at 60 tonnes.

Rosebery (Tas): In 2011, metal-in-concentrate produced at the Rosebery operations of MMG was 80.7 kt Zn, 25.4 kt Pb, 1.83 kt Cu and 0.378 tonnes Au⁹⁹. Total mine production was 13% higher than that achieved in 2010, but lower zinc grades resulted in 2% lower zinc in concentrate production, although lead in concentrate and copper in concentrate production increased by 9% and 12%, respectively, as a result of improved mill recoveries. Mill testing of ore from the nearby South Hercules mine was completed in the fourth quarter of 2011, with development possibly beginning in the third quarter of 2012. Successful near-mine exploration has increased mineral resources to their highest level in the 75 years of Rosebery operations. Rosebery currently has a mine life beyond 2020.

Golden Grove (WA): MMG's Golden Grove operation consists of the Scuddles and Gossan Hill underground mines and the Scuddles processing plant. In 2011, a greater emphasis was placed on zinc production, with a decrease in copper-in-concentrate of 35% to 21.7 kt. Zinc-in-concentrate and lead-in-concentrate also decreased by 4% and 3% to 70.7 kt and 7.5 kt, respectively, as a result of lower grades, which more than offset higher production. Silver and gold in the HPM (high precious metal) concentrate experienced different results with silver increasing by 14% to 41.87 tonnes and gold decreasing by 18% to 0.736 tonnes. The Scuddles mine was re-opened in April 2011. In the first half of 2011, approval was granted for development of a shallow copper resource at Gossan Hill. Development of this resource is scheduled to commence in the second half of 2012 and will extend mine life to 2019.

Broken Hill (NSW): In 2011, Perilya Limited increased ore production from its Southern Operations at Broken Hill, treating a total of 1.74 Mt, compared with 1.64 Mt in 2010. The increase in ore production resulted in increased production of metal-in-concentrate. Relative to 2010, zinc production increased by 10% to 70.1 kt and lead production increased by 0.4% to 51.5 kt. Silver production, on the other hand, was 41.6 tonnes, down by 7% from 44.7 tonnes in 2010. Current reserves and resources provide for at least 10 years of production at the Southern Operations. The Potosi-Silver Peaks operation is currently in development and the historic Broken Hill North Mine is the subject of a development study.

In 2010, CBH Resources Limited continued to push towards production at its Rasp Mine development, which had been placed on care and maintenance in June 2008. Approval from the NSW Department of Planning and Infrastructure for development was gained in January 2011 and development was approved by the Toho Board (see below) in February. Underground development began in April 2012 and the mine was opened in June. Full-scale production is now expected in mid 2012. On 1 July 2009, the mineral resource was 16.5 Mt at 6.6% Zn, 5.1% Pb and 89 grams per tonne (g/t) Ag. At an annual throughput of 0.75 Mtpa, annual production would be 48 kt Zn, 39 kt Pb and 72 tonnes Ag for a minimum mine life of 15 years. In September 2010, CBH Resources was taken over by Toho Zinc Company Limited of Japan.

⁹⁹ Values of 2010 Rosebery metal production differ significantly between the MMG 2010 and 2011 annual reports, with the values reported in 2011 significantly lower than the values reported in 2010. In this report, the 2011 metal production is compared with the 2010 values reported in the 2011 annual report.

Endeavor (NSW): Because of the takeover of CBH Resources by Toho Zinc in September 2010, production figures for zinc and lead at the Endeavor mine near Cobar in NSW are not available. However, the current operation plan involves mining of 0.720 Mt of ore for 44 kt of zinc-in-concentrate and 24 kt of lead-in-concentrate. Given these production rates, mine life is expected to be six years. Silver production, which is owned separately by Couer d'Alene Mines Corporation, was 19.1 tonnes, an increase of 8% over 2010.

Angas (SA): Operations began at Terramin Australia Ltd's underground Angas Mine in July 2008 at a setup cost of \$71 million. The mine reached nameplate production capacity of 0.4 Mtpa in the second half of 2009. Production for 2011 was 18.3 kt Zn, 8.7 kt Pb, 145 tonnes Cu, 8.6 tonnes Ag and 0.123 tonnes Au, all as payable metal. Production in 2011 of all metals except zinc matched or exceeded production in 2010. On 30 June 2011, Angas had reserves of 1.29 Mt at 7.2% Zn, 2.9% Pb, 31 g/t Ag and 0.5 g/t Au, which is sufficient for a further three-year operation at current production rates. Near-mine exploration resulted in delineation of the Sunter deposit in November 2011, with a total resource of 0.375 Mt grading 3.8% Zn, 1.6% Pb and 15 g/t Ag.

Mount Garnet-Chillagoe-Balcooma-Thalanga (Qld): At the end of 2011, Kagara Limited's north Qld zinc interests were centred on the Mount Garnet-Chillagoe region of north Qld and included mines at Mungana, Mount Garnet and Balcooma and ore processing facilities at Mount Garnet (separate facilities for copper and polymetallic ores) and Thalanga. Mill production in 2011 for all Kagara north Qld operations totalled 1.46 Mt of ore that yielded 56.4 kt of zinc-in-concentrate, 3.2 kt of lead-in-concentrate, 22.6 kt of copper-in-concentrate, 30.4 tonnes of silver-in-concentrate and 0.149 tonne of gold-in-concentrate, higher than the 2010 production by 48%, 170%, 27%, 92% and 41%, respectively. Much of this increase in production resulted from refurbishment of the Thalanga facility in 2010, which converted it from a copper-only circuit to a polymetallic facility with a capacity for oxide ores. In April 2012, Kagara Ltd went into voluntary administration, and its assets, including its north Qld operations, were on the market at the time of writing (see below).

Jaguar-Bentley (WA): The Jaguar project consists of three high-grade deposits, Jaguar, Teutonic Bore, and Bentley, located approximately 300 km north of Kalgoorlie. Perth-based Jabiru Metals Limited began operations at Jaguar in 2007 and the Bentley deposit was discovered in 2008, with production beginning in June 2011. Jabiru Metals Ltd was taken over by Independence Group in February 2011. Production in 2011 was 12.4 kt of zinc-in-concentrate and 7.03 kt of copper-in-concentrate from 0.358 Mt of ore. Although tonnage milled was similar to 2010, metal-in-concentrate production was down by 39% for zinc and by 27% for copper because of lower grades. In the June quarter, geotechnical issues impacted on mining of high-grade copper ore and resulting in the milling of ore from lower grade stopes and surface stockpiles.

Hellyer-Fossey (Tas): Following cessation of Bass Metals mining activities at its Que River Mine in September 2010, Bass Metals concentrated on developing and mining the Fossey and Fossey East deposits, which were discovered adjacent to the historical Hellyer Mine in 2007 and 2010, respectively. Work to develop a decline to access the Fossey deposit and refurbish the Hellyer mill began in January 2011. First ore production from Fossey was achieved in March. Production at Fossey for 2011 was 0.317 Mt of ore for 15.04 kt of zinc-in-concentrate, 6.61 kt of lead-in-concentrate, 0.277 kt of copper-in-concentrate, 23.57 tonnes of silver-in-concentrate, and 97.1 kg of gold-in-concentrate. Mining ceased at Fossey in May 2012 (see below).

Magellan (WA): Magellan Metals Pty Ltd, which is a wholly owned subsidiary of Toronto-listed Ivernia Inc, totally owns the Magellan deposit, 30 km west of Wiluna. Lead production at this deposit, which is the largest known carbonate lead deposit in the world, began in October 2005, with concentrates sold overseas and shipped initially from the Port of Esperance. However, because of lead contamination at the port, shipping was suspended and the mine was placed on care and maintenance in April 2007. Mine production recommenced in February 2010 following revision of concentrate transport procedures with the concentrate being shipped through the Port of Fremantle. However, production ceased again in early January 2011 following a stop order on the transportation of lead carbonate and the mine is again on care and maintenance.

Other zinc-lead-silver developments

There are several zinc-lead-silver prospects at various stages of development that could come online in the next decade. The most significant of the zinc-lead projects is the **Dugald River** deposit in Qld, owned by MMG. This deposit, the first new zinc deposit discovered in the Mount Isa region after Mt Isa, was the subject of a feasibility study in 2008, which was updated in 2010. The feasibility study indicated a mine life of 23 years based on a resource of 53 Mt grading 12.5% Zn, 1.9% Pb and 36 g/t Ag. Development approval was granted in December 2011 to bring the project to full environment approval, which was achieved in August 2012 for a possible start to production in 2014.

The next most advanced project is the Independence Group's **Stockman Project** (Vic) which includes the **Wilga** and **Currawong** volcanic-hosted massive deposits with a combined resource of 12.7 Mt grading 4.4% Zn, 0.7% Pb, 2.1% Cu, 39 g/t Ag and 1.0 g/t Au. At the time of writing this report, a definitive feasibility study and an Environmental Effects Statement were being prepared for this project. Another project for which a definitive feasibility study was completed is YTC Resources' **Hera-Nymagee Project** near Cobar in NSW. Based on a global resource of 2.44 Mt grading 3.8% Zn, 2.8% Pb, 0.2% Cu, 16.7 g/t Ag and 4.1 g/t Au, the feasibility study indicated a financially and technically robust project with a minimum 7.3-year mine life. This result would be enhanced by a significant resource (8.10 Mt grading 1.2% Cu, 0.7% Zn, 0.3% Pb and 9 g/t Ag) at the nearby **Nymagee** prospect.

Venturex Resources Ltd has consolidated many of the zinc-lead resources in the Pilbara region (WA) into its **Pilbara VMS Copper-Zinc Project**. The project includes the **Whim Creek, Mons Cupri, Salt Creek, Evelyn** and **Sulphur Springs** deposits. Current resources for the consolidated project total 26.3 Mt grading 3.0% Zn, 0.3% Pb, 1.2% Cu, 19.8 g/t Ag and 0.1 g/t Au. Release of a bankable feasibility study has been delayed from September 2012 until November 2012 to allow incorporation of new results from Sulphur Springs. Subject to board approval, finance and permitting, construction is scheduled to begin in the first half of 2013, with commissioning in the second half of 2014.

The **Myrtle Project** (NT) is located about 20 km south of the **McArthur River** deposit in the same host succession. The project, a joint venture between Rox Resources and Teck Australia, is still at the exploration stage, but has a total resource of 43.6 Mt grading 4.09% Zn and 0.95% Pb, with a higher grade resource of 15.3 Mt grading 5.45% Zn and 1.40% Pb. Exploration is continuing in the region, with identification of significant intersections from historic drilling highlighting the potential of the **Teena** prospect, about 10 km west of McArthur River.

At Kagara's **Admirals Bay** deposit in the Canning Basin (WA), a prefeasibility study identified mineral resources of 72 Mt grading 3.1% Zn, 2.9% Pb, 18 g/t Ag and 20% barite. However, this deposit is located more than a kilometre below the surface and requires a large injection of money to bring the project to bankable feasibility status. At the time of writing, this asset was out for tender as a consequence of Kagara Ltd going into voluntary administration.

Silver

The interest in deposits in which silver is the main or only commodity has continued, with mining and processing commencing at Alcyone Resources **Twin Hills** (Qld) mine in July 2011, and at Cobar Consolidated Resources **Wonawinta** (NSW) mine in May 2012. A number of other projects are also at various stages in the production pipeline, mostly in NSW and QLD, but also in SA and WA.

At its **Texas Project**, Alcyone Resources Ltd recommissioned the Twin Hills mine in February 2011. Initially, historic heap-leach stockpiles were re-irrigated, producing in excess of the budgeted 250 000 ounces (7087 kg) by September, at which time the crushing circuit had been upgraded and new ore was being added to the heap-leach pads. At the time of writing, the Texas Project has identified reserves sufficient to last five years.

At the **Wontawinta** deposit in the Cobar mineral field, Cobar Consolidated Resources Ltd treated the first batch of ore in May 2012, with pouring of the first silver in July. From the decision to mine in June 2011, mine construction took less than a year, with the first pour occurring just over a year after initial construction. Full production is expected in December 2012, with a mine life of 8-10 years. Cobar Consolidated Resources indicates that Wontawinta is not a typical Cobar-type deposit, but more likely a Mississippi Valley-type deposit.

Other silver projects in early stages of development in eastern Australia include Argent Minerals' **Kempfield** project (NSW), and Kingsgate Consolidated **Bowdens** project (NSW), both of which are the subject of feasibility studies. At Kempfield, updated resources at 26 April 2012 total 21.8 Mt grading 47 g/t Ag and 0.12 g/t Au with lead and zinc credits in primary ore. In addition, the deposit contains large amounts of barite. At Bowdens, a total resource of 58.2 Mt grading 52.9 g/t Ag, 0.40% Zn and 0.30% Pb has been defined. Other less advanced silver projects include Silver Mines Ltd's **Webbs Project** in NSW and White Rock Minerals's **Mount Carrington Project** in Qld. The Webbs Project currently has a total resource of 1.49 Mt grading 245 g/t Ag, 0.27% Cu, 0.71% Pb and 1.56% Zn. In July 2012, a scoping study on the Mount Carrington project using JORC-compliant mineral resource data released in February 2012 (12.21 Mt grading 58 g/t Ag and 0.2 g/t Au (Ag-rich) and 5.01 Mt grading 1.4 g/t Au and 2.8 g/t Ag (Au-rich)) indicated robust viability, and White Rock Minerals has been encouraged to undertake a prefeasibility study in 2013 with the aim of development in 2014.

Although silver exploration and development is occurring mostly in NSW and QLD, particularly in the New England and Lachlan Orogens, silver exploration has recommenced at MacPhersons Rewards **Nimbus Project** in WA and

Investigator Resources discovered previously unknown epithermal silver mineralisation at the **Paris** prospect in **Peterlumbo** silver field in SA. At Nimbus, which produced 112 tonnes of silver between 2003 and 2007, MacPhersons Reward has identified total resources of 2.792 Mt grading 112 g/t Ag, 0.12 g/t Au, 1.23% Zn, 0.20% Pb, 0.02% Cu and 98 parts per million mercury. In addition, the company has identified several massive sulfide zones with grades up to 41% Zn that are not considered in the resource. The company has added to the existing mill on site by purchasing additional equipment for a gold circuit.

Perhaps the most significant development in silver was Investigator Resources discovery of high-grade silver at the Paris prospect in the southern Gawler Province. This prospect, which was only discovered in January 2011, consists mainly of sheet-like zones and subvertical veins in dolomite just below the unconformity with Gawler Range volcanics. The silver is interpreted to be epithermal in origin and has some similarities to manto-type deposits.

Rocky roads

In contrast to 2010-11, when takeovers dominated the zinc-lead-silver sector, 2012 was dominated by financial difficulties for small to mid-tier producers, including Kagara Limited, Bass Metals and the Independence Group as a result, at least in part, of depressed zinc and lead prices. Kagara Limited went into voluntary administration on 30 April 2012 after suspending all operations earlier in the month. At the time of writing, the assets of Kagara, including its north Qld operations and the **Admiral Bay** deposit in WA, were up for tender.

Bass Metals ceased mining of the **Fossey** deposit in May 2012, with milling at the **Hellyer** mill finishing in June. LionGold of Singapore pulled out of an agreement to purchase the **Hellyer** mill in September, leaving the immediate future of Bass Metals unclear. Independence Group, which acquired the **Jaguar** and **Bentley** deposits after taking over Jabiru Mining in April 2011, reported impairments of \$157.7 million in December 2011 and \$98.7 million in June 2012 related to Jaguar-Bentley operations.

Resources to Production Ratios



Photo: Empty coal train near Rockhampton, Queensland, returning to the mine for refilling.

Resources to production ratios

The continuing contribution of mineral resources to Australia's economic performance in the medium and longer term will depend on the discovery and development of new, good quality resources. To assist with an assessment of the future supply capability of identified resources, an indicator of resource life using ratios of Accessible Economic Demonstrated Resources (AEDR) to current mine production are provided in the commodity review chapters. Ratios of ore Reserves to production are a much more conservative indicator of what is likely to be available for mining in the foreseeable future. It is important to note that these duration indicators can change rapidly with significant variations in rates of production and/or major changes to resources.

Table 21 presents a comparison of the AEDR/production ratios from 1998 to 2011. During this 14 year period there has been a persistent long-term decline in the AEDR/production ratio for black coal, iron ore and rutile, which reflect major increases in production and reassessment of resources. The decline in iron ore prior to 2008 has been partly offset by the development of large magnetite iron ore deposits in the Pilbara and mid-west regions of Western Australia. These magnetite resources, which were previously considered to be subeconomic, are becoming increasingly more viable. There was also a reversal in the decline of the AEDR/production ratios for black coal, brown coal and rutile in 2011.

Commodities with a resource life of less than 50 years are manganese ore (about 15 years at current rates of production), diamond and gold (35 years), and zinc (45 years). There is a need for ongoing successful exploration in the short and medium term to ensure sufficient available resources to maintain Australia's levels of exports of these commodities.

Increases in the AEDR/production ratios during 2011 were recorded for black coal, brown coal, diamond, rutile, uranium, lead and silver, with reduced production (rather than increases in resources) accounting for increases in the AEDR/production ratios for uranium.

At the same time, reductions in AEDR/production ratios during 2011 were recorded for copper, iron ore, ilmenite, zircon, and nickel with recoveries in production levels for some commodities being partly responsible for a reduction in AEDR/production ratios.

It is important to note that a long resource life for a particular commodity is not a guarantee that such resources will continue to be exploited in Australia. In an increasingly globalised and competitive commodity market, multinational mining companies are continuously searching for mineral deposits that offer the most attractive returns on investment. Such returns are influenced not only by the quality of the resources (grade and tonnage) but also by the environmental, social and political factors, land access, infrastructure and the location and scale of the existing mining operations owned by the company.

The world financial crisis in 2008 exacerbated these factors and forced many companies to reassess their options for both existing and planned operations in Australia. In the case of black coal and iron ore, the initial impact of the world financial crisis caused some mining operations to scale back production while others delayed plans for expansion and some mines closed at the end of 2008. However, by mid 2009, recovery in mining operations and development plans were well under way for the affected commodities but this trend was less pronounced in 2011.

During 2009 and 2010, some multinational companies closed sulphide and lateritic nickel mines in Western Australia and Tasmania and consolidated their operations at larger low-cost mining operations, although not necessarily in Australia. This is a consequence of the dominance of large multinational mining companies in the world mining industry. A number of these nickel mines resumed production by 2011 and the large Ravensthorpe lateritic nickel mine was refurbished during 2010/11 followed by restart of operations during the second half of 2011.

The AEDR/production ratio for copper dropped by 10% in 2011 as new and re-opened copper mines contributed to production increases in conjunction with only a slight rise in EDR. In contrast, over the previous 13 years the ratio had increased progressively with increasing resources particularly at Olympic Dam.

AEDR/production ratios for zinc, lead and silver have increased slowly over the past 14 years. Mine production and resources of zinc, lead and silver also have increased over this period.

Table 21. Years of Accessible Economic Demonstrated Resources (AEDR) at the production level for each year (rounded to nearest 5 years).

Commodity	1998	2003	2008	2009	2010	2011
Bauxite	70	90	85	85	80	80
Black Coal	180	110	90	100	90	110
Brown Coal	630	440	490	470	495	510
Copper	40	50	85	95	100	90
Diamond	3	5	10	20	30	35
Gold	15	20	30	30	30	35*
Iron Ore	100	60	70	70	80	75
Lead	30	30	40	55	50	60
Manganese Ore**			20	20	15	15
Mineral Sands						
Ilmenite	70	85	85	110	125	120
Rutile	75	90	55	70	45	50
Zircon	60	50	55	70	60	50
Nickel	65	120	130	145	120	95
Silver	30	25	30	45	40	50
Uranium	105	80	125	140	175	180
Zinc	30	25	35	45	45	45

* Average AEDR/production ratio for gold (35 years) is strongly influenced by low-grade copper-gold deposits with ratio of over 65 at current rates of mine production, whereas lode gold deposits have AEDR/production ratio of less than 20 years.

** AEDR/production ratios allows for losses that occur in beneficiating (upgrading) manganese ores.

During 2011, higher gold prices and exploration expenditure coincided with the definition of a further 743 tonnes of EDR. Domestic mine production decreased marginally from 260 to 258 tonnes with the drop in output from gold-dominant operations nearly offset by increased output from by- and co-product producers. The resources to production ratio for gold increased from 30 to 35 years for 2011 reflecting the increases in resources relative to essentially steady production levels. As indicated for 2010 though, the average resource to production ratio masks the industry characteristics in which over 65% of production is derived from lode-gold deposits which account for only 36% of resources (resource to production ratio of 19 years), while copper-gold deposits account for 60% of resources but only contribute 31% of production (resource to production ratio of 67 years).

For heavy mineral sands operations, some producers closed down low-grade ilmenite deposits in 2008 to concentrate on deposits that are more readily amenable to beneficiation, or have higher zircon content. However, sharply lower levels of production of ilmenite, rutile and zircon in 2009 resulting from the flow-on effects of the global financial crisis in late 2008 and early 2009, led to increases in resource life in 2010. In 2011, production of ilmenite continued to decrease with 1.277 Mt, but production of rutile, and zircon increased to 474 000 tonnes of rutile and 762 000 tonnes of zircon compared with 1.313 Mt of ilmenite, 430 000 tonnes of rutile and 540 000 tonnes of zircon in 2010. This resulted in a further decrease in AEDR/production ratios for ilmenite due to a decrease in ilmenite EDR, an increase for rutile due to an increase in rutile EDR, but a decrease for zircon due to a massive increase in zircon production despite an increase in zircon EDR.

For uranium, AEDR/production ratios have increased progressively since 2003. For the period 2003 to 2009 this was due to increases in Australia's uranium resources mostly from ongoing evaluation of the Olympic Dam deposit (Expansion project). From 2009 onwards, increases in this ratio resulted from lower uranium production caused by operational problems at each of the three uranium mines (damage to a haulage shaft at Olympic Dam, flooding of the Ranger 3 pit and operating problems at Beverley). Increases in mining and processing costs have limited the growth of Australia's AEDR over recent years.

Appendices



Photo: Aerial view of reclaimer working iron ore stockpile at Karratha shipping terminals, Western Australia.

Appendix 1

Abbreviations and Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences	ML	million litres
ABS	Australian Bureau of Statistics	Moz	million ounces
A\$	Australian dollar (where not stated, assume Australian currency)	Mt	million tonnes
AEDR	Accessible Economic Demonstrated Resources	Mtpa	million tonnes per annum
BREE	Bureau of Resources and Energy Economics	MW	megawatt
BRS	Bureau of Resource Sciences	MWe	megawatt electric
c	carat	NSW	New South Wales
cpht	carats per hundred tonnes	NT	Northern Territory
CSIRO	Commonwealth Scientific and Industrial Research Organisation	OECD/NEA	Organisation for Economic Cooperation and Development/Nuclear Energy Agency
EDR	Economic Demonstrated Resources	oz	ounce
GIS	geographical information system	PDR	Paramarginal Demonstrated Resources
g	gram	PGE	platinum-group elements
g/t	grams per tonne	PJ	petajoules
GL	gigalitre	ppm	parts per million
Gt	gigatonne	Qld	Queensland
IAEA	International Atomic Energy Agency	RAR	Reasonably Assured Resources
JORC	Joint Ore Reserve Committee – <i>Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves</i>	REO	rare earth oxide
kg	kilogram	REE	rare earth element
km	kilometre	SA	South Australia
kt	kilotonne (thousand tonnes)	SDR	Subeconomic Demonstrated Resources
ktpa	kilotonne per annum	Tas	Tasmania
LNG	liquefied natural gas	tpa	tonnes per annum
m	metre	USA	United States of America
Mc	million carats	USGS	United States Geological Survey
MEL	mineral exploration licence	US\$	United States of America dollar
		Vic	Victoria
		WA	Western Australia
		\$1M	million dollars

Appendix 2

AUSTRALIA'S National Classification System for Identified Mineral Resources (2009 edition)

Introduction

Australia's mineral resources are an important component of its wealth, and a long-term perspective of what is likely to be available for mining is a prerequisite for formulating sound policies on resources and land access.

In 1975, Australia (through the Bureau of Mineral Resources, which has evolved to become Geoscience Australia) adopted, with minor changes, the McKelvey resource classification system used in the USA by the then Bureau of Mines and the United States Geological Survey (USGS). Australia's national system remains comparable with the current USGS system, as published in its *Mineral Commodity Summaries*.

Companies listed on the Australian Securities Exchange are required to report publicly on ore reserves and mineral resources under their control, using the Joint Ore Reserves Committee (JORC) Code (see <http://www.jorc.org/>). This has also evolved from the McKelvey system, so the national system and JORC Code are compatible. Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources.

Estimating the total amount of each commodity likely to be available for mining in the long term is not a precise science. For mineral commodities, the long-term perspective takes account of the following:

- JORC Code Reserves will all be mined, but they only provide a short term view of what is likely to be available for mining.
- Most current JORC Code Measured and Indicated Resources are also likely to be mined.
- Some current JORC Code Inferred Resources will also be transferred to Measured Resources and Indicated Resources and Reserves.

New discoveries will add to the resource inventory.

Classification principles

The national system for classification of Australia's identified mineral resources is illustrated in **Figure A1**. It classifies Identified (known) Mineral Resources according to two parameters, the degree of geological assurance and the degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and grade while the latter takes account of economic factors such as commodity prices, operating costs, capital costs, and discount rates.

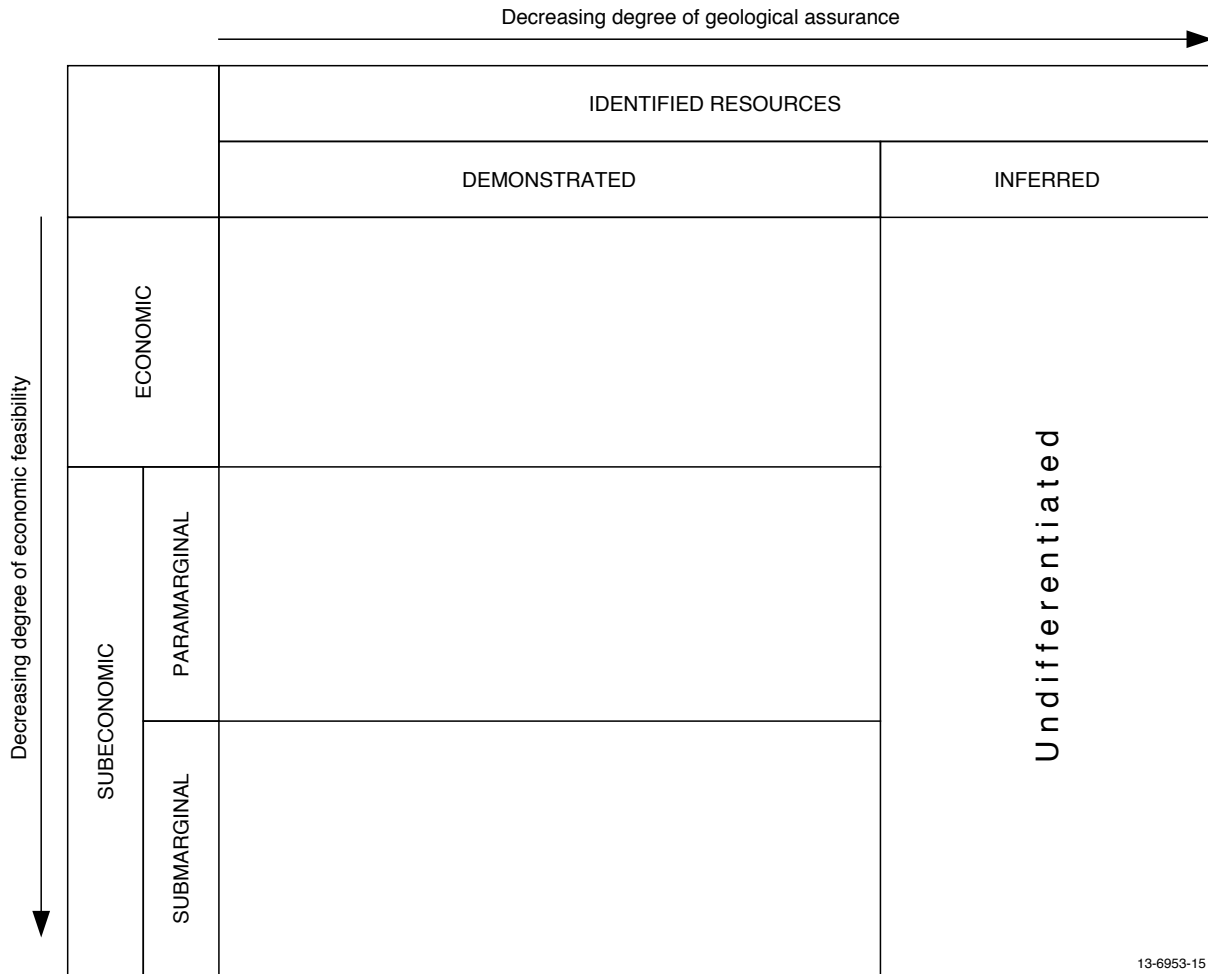


Figure A1. Australia's national classification system for mineral resources.

Resources are classified in accordance with economic circumstances at the time of estimation. Resources that are not available for development at the time of classification because of legal and/or land access factors are classified without regard to such factors, because circumstances could change in the future. However, wherever possible, the amount of resource affected by these factors is stated.

Because of its specific use in the JORC Code, the term 'Reserve' is not used in the national inventory, where the highest category is '**Economic Demonstrated Resources**' (EDR, Figure A1). In essence, EDR combines the JORC Code categories 'Proved Reserves', 'Probable Reserves', plus 'Measured Resources' and 'Indicated Resources' as shown in Figure A2. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term.

Terminology and definitions for Australia's national system

'Resource': A concentration of naturally occurring solid, liquid or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially (within a 20-25 year timeframe) feasible.

The definition does not intend to imply that exploitation of any such material will take place within that time span, but that exploitation might reasonably be considered. It should be applied also on a commodity by commodity basis to take account of prevailing and prospective technologies. The term includes, where appropriate, material such as tailings and slags. Mineralisation falling outside the definition of 'Resource' is referred to as an 'occurrence' and is not included in the national inventory.

'Identified Resource': A specific body of mineral-bearing material whose location, quantity, and quality are known from specific measurements or estimates from geological evidence for which economic extraction is presently or potentially possible.

Categories based on degree of geological assurance of occurrence

To reflect degrees of geological assurance, Identified Resources are divided into Demonstrated Resources and Inferred Resources:

1. **'Demonstrated Resource'**: A collective term used in the national inventory for the sum of 'Measured Mineral Resources', 'Indicated Mineral Resources' 'Proved Ore Reserves' and 'Probable Ore Reserves' (see Figure A2), which are all defined according to the JORC Code:
 - A **'Measured Mineral Resource'** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.
 - An **'Indicated Mineral Resource'** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.
 - A **'Proved Ore Reserve'** is the economically mineable part of a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.
 - A **'Probable Ore Reserve'** is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.
2. An **'Inferred Mineral Resource'** is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which may be limited or of uncertain quality and reliability.

By definition, Inferred Resources are classified as such for want of adequate knowledge and therefore it may not be feasible to differentiate between economic and Subeconomic Inferred Resources. Where the economics cannot be determined, these Inferred Resources are shown as 'undifferentiated'.

Categories based on economic feasibility

Identified resources include economic and subeconomic components.

1. **'Economic'**: Implies that, at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.
2. **'Subeconomic'**: Refers to those resources which do not meet the criteria of economic; Subeconomic Resources include Paramarginal and Submarginal categories:
 - **'Paramarginal'**: That part of Subeconomic Resources which, at the time of determination, could be produced given postulated limited increases in commodity prices or cost-reducing advances in technology. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria for economic.
 - **'Submarginal'**: That part of Subeconomic Resources that would require a substantially higher commodity price or major cost-reducing advance in technology, to render them economic.

The definition of 'economic' is based on the important assumption that markets exist for the commodity concerned. All deposits that are judged to be exploitable economically at the time of assessment are included in the economic resources category irrespective of whether or not exploitation is commercially practical. It is also assumed that producers or potential producers will receive the 'going market price' for their production.

The information required to make assessments of the economic viability of a particular deposit is commercially sensitive. Geoscience Australia's assessment of what is likely to be economic over the long term must take account of postulated price and cost variations. Economic resources include resources in enterprises that are operating or are committed, plus undeveloped resources that are judged to be economic on the basis of a realistic financial analysis, or compare with similar types of deposits in operating mines.

How is the national inventory compiled?

Virtually all of the mineral resource estimates compiled by Geoscience Australia's commodity specialists, including Subeconomic Resources, originate from published mining company sources reporting under the JORC Code. Given the common resource categories and definitions, the transfer of mineral resources from company reports into Australia's national mineral resource categories is quite straightforward, as summarised in Fig. A2.

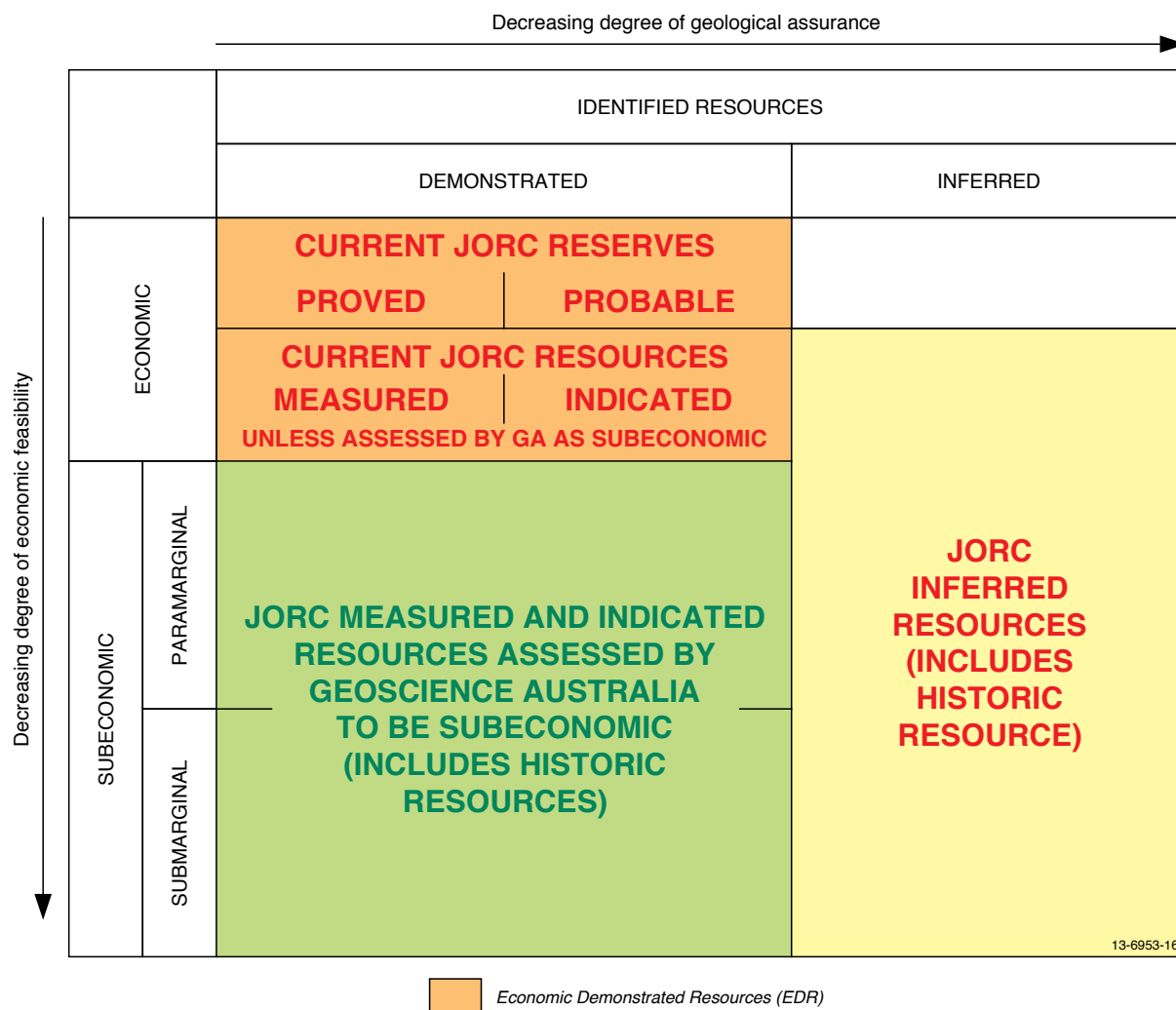


Figure A2. Correlation of JORC Code mineral resource categories with Australia’s national mineral resource classification system.

Notes:

- i. EDR comprise mainly current JORC Code reserves and resources, but minor proportions of EDR come from selected historic JORC Code and pre-JORC Code reserves and resources;
- ii. In some instances, where a deposit is reported as having Measured and/or Indicated Resources, particularly where there are no Reserves reported, a professional judgement is made by Geoscience Australia as to whether all or part of the reported Resources are included in EDR, or assessed as subeconomic; and
- iii. Subeconomic Resources are largely from historic company reports but are still the most recent estimates, and it also includes proportions of resources from current company reports which are JORC Code compliant but have been assessed by Geoscience Australia as subeconomic.

In essence, for the reasons outlined above, the national inventory is compiled by:

- Incorporating the JORC Code Proved and Probable Ore Reserves and Measured and Indicated Mineral Resources into EDR.
- Transferring JORC Code Inferred Resources to the national Inferred Resources category. There is commonly insufficient information to determine whether or not Inferred Resources are economic.

In addition, Geoscience Australia makes decisions on the transfer of historic JORC Code and pre-JORC Code estimates of ore reserves and mineral resources. Some of these old estimates are economically less attractive under current conditions, usually due to lower commodity prices and/or unforeseen technical problems. Some of these resources may be removed from EDR and transferred to Paramarginal or Submarginal Resources. However, if such resources cannot be reasonably expected to become economic within a time frame of 20 to 25 years, they are removed from the national mineral resources database.

Companies report grade and tonnage data for individual deposits. However, it is not meaningful to add up grades and tonnages from different deposits, so the national inventory reports only the aggregated total tonnage for each commodity – that is, the sum of the contained metal in individual deposits for each resource category, which has been derived from company reports.

Allowances for losses

Loss of resources resulting from mining and milling (metallurgical processing) are given for the reserve and resource categories of the JORC Code. The allowances for losses, which apply to all minerals except coal, uranium, thorium and oil shale, are summarised in Table A1.

Table A1. Allowance for mining and milling losses in the National and JORC Code systems.

National system	JORC Code system	Mining losses	Milling (metallurgical) losses
DEMONSTRATED RESOURCES	Proved Ore Reserves	Deducted	Not deducted - but are considered in assessing economic viability
	Probable Ore Reserves	Deducted	Not deducted - but are considered in assessing economic viability
	Measured Mineral Resources	Not deducted	Not deducted
	Indicated Mineral Resources	Not deducted	Not deducted
INFERRED RESOURCES	Inferred Resources	Not deducted	Not deducted

Exceptions:

- i. For **coal**, the following resource categories are used – ‘Recoverable coal resources’ makes allowance for mining losses only. ‘Saleable coal’ makes allowance for mining as well as processing losses.
- ii. **Uranium and thorium** resources are reported with losses resulting from mining and milling deducted from all categories, consistent with the international uranium resource classification system of the OECD Nuclear Energy Agency and International Atomic Energy Agency.
- iii. **Oil Shale** resources are reported as recoverable oil.

Correlation of Australia’s national classification system for mineral resources with United Nations Framework Classification system

In order to compare Australia’s national inventory of mineral resources with those of other countries and estimate total global stocks, it is useful to map different systems onto a common international classification template.

The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC 2009) is an internationally applicable generic principle-based system in which mineral resource categories are classified on the basis of the three fundamental criteria of:

- economic and social viability (E),
- project status and feasibility (F), and
- geological knowledge (G).
- Mineral resource ‘classes’ are defined by using a numerical coding system ordered in a three-dimensional system along the three axes of E, F and G with ‘1’ being the highest category in terms of quality and knowledge and ‘4’ the lowest.
- A mineral resource class is defined by selecting from each of the three criteria a particular combination of a category or a sub-category.
- The codes are always quoted in the same sequence (e.g., E1; F1; G1),
 - The letters may be dropped and just the numbers retained, for example 111 at class level or 3.2; 2.2; 1,2 at sub-class level; and
 - These criteria may be further subdivided.

A full description of the UNFC system can be accessed at <http://www.unece.org/energy/se/reserves.html>

UNFC Classes defined by categories and sub-categories							
Total commodity initially in place	Extracted	Sales production					
		Non-sales production					
		Class	Sub-class	Categories			
E	F			G			
Known deposit	Commercial projects	On production	1	1.1	1	2	
		Approved for development	1	1.2	1	2	
		Justified for development	1	1.3	1	2	
	Potentially commercial projects	Development pending	2	2.1	1	2	3
		Development on hold	2	2.2	1	2	3
	Non-commercial projects	Development unclarified	3.2	2.2	1	2	3
		Development not viable*	3.3	2.3	1	2	3
Additional quantities in place		3.3	4	1	2	3	
Potential deposit	Exploration projects	(No sub-classes defined)	3.2	3			4
	Additional quantities in place		3.3	4			4

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Australia's National Resource System

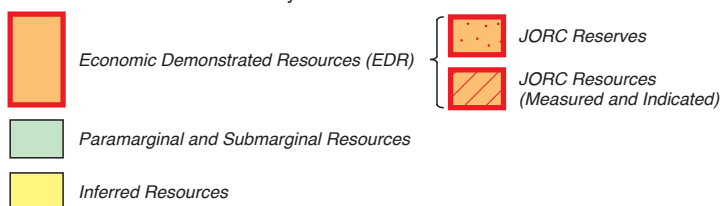


Figure A3. Correlation of Australia's national mineral resource classification system with United Nations Framework Classification (UNFC) system.

As discussed previously (Figure A2), Geoscience Australia's EDR comprises JORC Reserves and JORC Resources where:

- the JORC Reserves component of EDR correlates with the UNFC's class of 'Commercial Projects' (as defined by mineral resource categories 111 and 112 in Figure A3); and
- the JORC Resources component correlates with 'Potentially Commercial Projects' (as defined by categories 221 and 222).
- Australia's national Subeconomic Resources (Paramarginal and Submarginal) correlate with a subclass of UNFC's 'Non-Commercial Projects' (categories 3.2; 2.3; 1,2).
- Geoscience Australia's Inferred Resources are identified by the UNFC geological criterion G3 and is defined by 223.

UNFC's mineral resource classes under 'Potential Deposits' comprise Exploration Results under the JORC Code and various types of quantitative estimates of undiscovered mineral resources which are not currently assessed under Geoscience Australia's national mineral resource system.

Appendix 3

Mineral resources and advice project: staff, contacts and credits

Name	Telephone	Email	Commodity
Leesa Carson (Group Leader)	+ 61 2 6249 9872	leesa.carson@ga.gov.au	Shale oil
Aden McKay (Section Leader)	+ 61 2 6249 9230	aden.mckay@ga.gov.au	Uranium, tin
Steve Cadman	+ 61 2 6249 9280	steve.cadman@ga.gov.au	Black coal, brown coal
Yanis Miezitis	+ 61 2 6249 9523	yanis.miezitis@ga.gov.au	Nickel, PGE, cobalt, mineral sands, rare earths, potash, thorium, chromium
Keith Porritt	+ 61 2 6249 9479	keith.porritt@ga.gov.au	Copper, zinc, lead, silver
Daisy Summerfield	+ 61 2 6249 9357	daisy.summerfield@ga.gov.au	Iron ore
Alan Whitaker	+ 61 2 6249 9702	alan.whitaker@ga.gov.au	Gold
Allison Britt	+ 61 2 6249 9647	allison.britt@ga.gov.au	Phosphate, vanadium, bauxite-alumina-aluminium
Roy Towner	+61 2 6249 5828	roy.towner@ga.gov.au	Magnesite
Subhash Jaireth	+61 2 6249 9419	subhash.jaireth@ga.gov.au	Tantalum, niobium
Michael Sexton	+ 61 2 6249 9262	michael.sexton@ga.gov.au	Manganese ore, Information management and project data support
David Champion	+ 61 2 6249 9215	david.champion@ga.gov.au	Molybdenum, tin, tungsten
David Huston	+ 61 2 6249 9577	david.huston@ga.gov.au	Zinc, lead, silver
Anthony Schofield	+ 61 2 6249 9833	anthony.schofield@ga.gov.au	Diamonds
Dean Hoatson	+ 61 2 6249 9593	dean.hoatson@ga.gov.au	Rare earths

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Photographs are from Peter Robey Photography.
Edited by Alan Reid, Allison Britt and Aden McKay.
Accessibility by Allison Britt, Robin Swindell and Adrian Yee.



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